External Technical Review of the Hanford K Basins Sludge Treatment Project

June 2009

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Abbreviations and Acronyms

ALARA	as low as reasonably achievable
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CHPRC	CH2M HILL Plateau Remediation Company
Ci	Curies
CTE	Critical Technology Element
CVDF	Cold Vacuum Drying Facility
DNFSB	Defense Nuclear Facilities Safety Board
DOE	U. S. Department of Energy
DOE-EM	U. S. Department of Energy Office of Environmental Management
DOE-RL	U. S. Department of Energy Richland Operations Office
DSB	Decision Support Board
DTC	Dose-to-Curie
EPA	U. S. Environmental Protection Agency
ETR	External Technical Review
FGE	fissile gram equivalent
IRC	Independent Review Committee
IWTS	Integrated Water Treatment System
KOP	knock out pots
MASF	Maintenance and Storage Facility
MCO	Multicanister Overpack
PCM	Primary Cleaning Machine
RH-TRU	Remote Handled Transuranic Waste
ROD	Record of Decision
SNF	Spent Nuclear Fuel
STP	Sludge Treatment Project
STSC	Sludge Transport and Storage Container
STS	Sludge Transport System
TRA	Technology Readiness Assessment
TRL	Technology Readiness Level
TRU	transuranic waste
U	Uranium
WIPP	Waste Isolation Pilot Plant

Acknowledgement

The Review Team thanks Mr. Thomas Teynor, DOE Richland Field Office (RL), and Mr. James Honeyman, CH2M HILL, Plateau Remediation Company for their exceptional support during this review. Mr. Teynor is the lead Department of Energy (DOE) Federal Project Director for the Sludge Treatment Project and organized the reviews held on-site by the Review Team. Mr. Honeyman and his colleagues provided responsive support through technical presentations, telephone conferences, and numerous reference documents.

The Review Team also acknowledges the excellent support provided by Dr. Steven Ross, U.S. Department of Energy Office of Environmental Management (DOE-EM), Office of Waste Processing. Dr. Ross supported the team throughout the review, and assisted in the preparation of this final report.

Executive Summary

The K Basin Sludge Treatment Project (STP) is responsible for sampling and analysis, retrieval, treatment, interim storage, packaging, and shipping of sludges currently located within the K West Basin in the 100 Area (along the Columbia River Corridor) at the U. S. Department of Energy (DOE) Hanford Site in Washington State. The following materials currently present in the K Basin are to be managed as part of the project: (i) sludge currently stored in engineered containers (engineered container sludge); (ii) settler tube sludge; and, (iii) knock-out pot (KOP) material[1]. Although additional basin vacuuming will occur prior to basin decommissioning activities, this material will be either dispositioned as engineered container sludge or fuel scrap[2]. The composition of the sludge in the engineered containers consists of iron and aluminum oxides, concrete grit, sand, dirt, paint chips, and operational and biological debris. It is contaminated with fuel corrosion products and small fragments of uranium (U). The sludge in the Settler Tanks ranges in particle size from a few microns to <600 microns. Chemically, the U is expected to be primarily U corrosion products and fission and activation products, with some remaining metallic U. The KOP material is anticipated to contain metallic U and U corrosion products along with non-U material (e.g., aluminum corrosion products and aluminum wire from fuel canisters). The project plans to wash the KOP material to remove sludge and non-U particulates to the extent practicable.

Discrete potential sludge processing functions are:

- Sludge Mobilization[3]: Mobilization and removal of the sludge from the storage containers;
- Pretreatment: Physical separation of U metal or U material from a sludge stream;
- Treatment: The oxidation of U metal to mitigate hydrogen generation, regardless of whether pretreatment function is applied;
- Interim Storage: Storage of the sludge on the Hanford Site as a slurry prior to packaging;
- Sludge Transfer: Movement of sludge between other identified functions;
- Packaging: Incorporation of sludge into a waste form suitable for disposal at Waste Isolation Pilot Plant (WIPP);
- On-site Transportation: Transportation of the sludge slurry or packaged material in a container within the confines of the Hanford Site using existing approved casks[4];
- WIPP Certification and Transport: Certification that the final waste form package meets WIPP transport and disposal requirements, and transport of the waste package to WIPP.

[1] Sludge is defined as any solid materials passing through a 0.25” screen.
[2] Uranium scrap is defined as fuel fragments greater than 0.25 inch and is the responsibility of the K Basin deactivation project, not STP. Any “found fuel” would also be the responsibility of the K Basin deactivation project.
[3] Throughout this document, sludge mobilization inherently implies retrieval as well.
[4] The current project plan is to use existing previously approved casks (technically their approval has expired). It is still possible, but unlikely, that new shipping containers may be used.

Additional characterization of these sludge materials is in-progress, and/or planned, to provide confirmatory analysis for process development and design and to support nuclear material accountability. KOP material is being characterized through in-basin inspections; the need for additional laboratory characterization is being evaluated by the project.

To carry out an alternatives analysis on the Engineered Container & Settler Tube Sludge Streams, the site contractor grouped together functions to form integrated alternatives for sludge processing. Not all of these functions are necessarily needed as part of an individual alternative. The necessary processing steps, technologies, facilities, and transportation methods were then combined into multiple, unique alternatives to potentially accomplish the sludge treatment project mission with the resulting set of potential alternatives then down selected to seven representative alternatives.

The schedule analysis focused on the critical path of several alternatives to remove sludge away from K Basins and the Columbia River and subsequently process it for shipment to WIPP. Three alternatives, Alternatives 1, 6, and 7, utilize a two phase approach. Alternative 1 would oxidize (treat) the sludge within K Basin, and then transfer the treated sludge to the Central Plateau for interim storage, with packaging completed after interim storage. Alternatives 6 and 7 would transfer the sludge as slurry to the Central Plateau 200 Area for storage, treatment, and packaging (see Table 2, below, for details; CHPRC 2009a, Rev. 0, Vol. 1). The project phases would be divided as follows:

Phase 1 – Removal of sludge and related materials from K Basins, including materials from engineered containers, and settler tubes, on-site transportation (as needed) and interim storage; and,

Phase 2 – Retrieval of sludge from interim storage containers, treatment (Alternatives 6 and 7, only), packaging, storage, and preparation for shipment to WIPP.

Analysis of these alternatives indicates removal of the sludge from K West Basin five to nine years faster than Alternatives 2 through 5, which package sludge at the K Basins. Thus, Alternatives 1, 6, and 7 are consistent with the DOE and U.S. Environmental Protection Agency (EPA) Region 10 objectives to remove the sludge off the River Corridor as soon as possible and achieve the "Hanford 2015 vision" for the Columbia River Corridor, providing comparative benefit to Alternatives 2 thru 5. As currently envisioned, interim storage in the Hanford 200 Area Central Plateau will be in either T Plant or a new facility. Facilities for treatment and packaging have not been identified.

No formal alternatives analysis was prepared for the KOP material. While disposition of the KOP material will occur during the timeframe that Alternative Analysis Phase 1 activities are implemented, KOP disposition is not considered a part of Phase 1.

This External Technical Review (ETR) evaluated the areas of project management, technical risks, regulatory risks, system risks, and safety risks emphasizing a systems approach for the STP to achieve its mission objectives. The following are the recommendations and associated discussion providing the supporting rationale resulting from this review.

In-basin Treatment versus Out-of-basin Treatment

RECOMMENDATION 1. DOE should explicitly state the priority objectives to guide the STP decision processes. If removal of sludge from the River Corridor prior to 2015 is the clear programmatic priority, then the phased approach of removal of sludges from the K Basin to interim storage at the Central Plateau, followed by treatment, packaging, and shipment is necessary to meet this objective.

Discussion. Achievement of the 2015 Vision (DOE 2009) and the programmatic preference expressed by both the U. S. Department of Energy Richland Operations Office (DOE-RL) and EPA to remove the sludge from the River Corridor by approximately 2015 were the primary determinants for selecting the two phased approach whereby sludge would be removed from K West Basin, transported to an interim facility at the Central Plateau where it would be stored, treated, and packaged for shipment to WIPP. The EPA considers the continuing presence of the sludge at the basin, delays in closure of the K Basins, and impediments posed by the basin to remediation of subsurface chromium contamination in the K Area as significant environmental risks and high priorities for Hanford remediation. The two phase approach was the only general project approach with a realistic opportunity to achieve the Hanford 2015 vision for the River Corridor and this, coupled with the stated EPA preference for the 2015 time period, were the primary factors that influenced the expert elicitation and alternatives evaluation process.

RECOMMENDATION 2. Both the technical and programmatic bases for selecting out-of-basin treatment should be clearly documented including attributes that favor and disfavor in-basin versus out-of-basin sludge treatment and packaging; the impact of these assumptions on cost and schedule estimates should be explicitly addressed.

Discussion. There are several technical factors that favor out-of-basin treatment and packaging of sludge retrieved from K West Basin, including reduced worker radiation dose, worker productivity concerns, present knowledge of sludge inventory and characteristics, and the complexity associated with designing and implementing an underwater process in the basin; these factors were significant considerations in the deliberations of project personnel, but are incompletely captured in the alternative selection basis. However, several factors also disfavor out-of-basin treatment, including: the possibility of delays in completing treatment and shipment of sludge after removal from the basins and Columbia River Corridor clean-up is achieved, i.e., absence of regulatory/schedule pressure; the potential need for additional sludge transfers to achieve treatment and packaging; and the potential for adverse changes in sludge characteristics during interim storage, making subsequent transfers, and treatment more difficult. Facilities (existing or new) will have be identified and either modified or constructed for interim storage and material packaging regardless of whether treatment occurs at K Basin or at the Central Plateau.

Primary Technical Project Components and Technical Risks

RECOMMENDATION 3.

a. Design of the interim storage configuration should be closely coupled to the selection and maturation of Phase II processing. An alternatives analysis and alternative selection process for Phase II treatment and packaging should be performed as soon as possible to facilitate integration of Phase I retrieval, Sludge Transport and Storage Container (STSC) design and storage strategy with Phase II treatment and packaging approaches. Alternatives analysis should include consideration of in-situ treatment (e.g., heated storage) followed by in-situ solidification and disposal in the interim storage container. The Technology Readiness Assessment (TRA)/ Technology Maturation Plan process should be used to inform the process development for Phase II.

b. Sampling and analysis of settler tube sludge during Phase I should include provision for direct measurement of hydrogen generation rates and quantities at controlled elevated temperature, in an appropriate environment, to facilitate planning and design of the Phase II treatment process.[5] Sufficient samples of engineered container sludge should be obtained to permit direct measurement of hydrogen generation rates if prior data is insufficient to support selected treatment conditions. Characterization of KOP material should be sufficient to bound the metallic U for quantity, particle size distribution, and surface area to adequately plan for (i) the number of Multicanister Overpacks (MCOs) to be produced; (ii) validate acceptable levels of hydrated material; and (iii) the potential for enhanced chemical reactivity of the material.

c. High priority should be given to maintaining and utilizing the Maintenance and Storage Facility (MASF) facility for design, operator training and troubleshooting throughout Phases I and II of the project. The MASF facility, employing appropriate surrogates, should be used to demonstrate (i) all sludge retrieval operations from within the basins (e.g., from engineered containers, settler tubes, KOPs), (ii) retrieval of sludges from STSCs after sludge settling, and (iii) solids handling in any proposed processing flowsheet (in-situ or using a separate plant). Solids handling processes such as these have a history of handling problems within the DOE complex and in commercial industry. Scaling up such processes is often difficult particularly when the nature of the solids is variable such as with the K Basin sludges. Full scale testing using a variety of simulants will reduce this uncertainty and improve the likelihood of success.

Discussion. Currently, the project does not have a well defined processing path for treatment and packaging of sludges after removal from the K Basin and transfer to interim storage. The absence of such a well defined processing path prior to removal from the K Basin, including timely technical maturation, produces the potential for scenarios where the ability to retrieve the sludge from interim storage containers and process the material creates unforeseen challenges and overall project inefficiencies, including additional future sampling and characterization, technology development and extended schedules for final disposition of the material.

[5] Measurement only of U metal content is insufficient because knowledge of the amount of U metal content will allow estimation of the total amount of hydrogen to be generated but not the rate of hydrogen generation because the particle size distribution of the U metal particles is not known (the combined particle size distribution of U metal and non U metal particles is measured and therefore the reactive surface area of U metal is not known).

The following are the primary technical components of the project and technical risks, as the ETF team has come to understand them:

a. *Retrieval of sludges from engineered containers and settler tubes.* The technical risks of these operations are associated mechanical and hydraulic operations to achieve sludge retrieval. Full-scale component and integrated testing at the MASF, including direct involvement of basin operators and feedback leading to design improvements, is an appropriate risk mitigation strategy. Appropriate bounding simulants for physical properties are in the process of being defined. This is an important matter because typically there are the problems associated with sampling materials comprised of fines or coarse particulates or a combination of both. Current measurement techniques such as yield strength may not be a sufficient discriminator for a mixture of granular and fine solids and therefore additional sludge characterization and simulant testing may be needed to provide confidence in equipment demonstration using simulants.

b. *Design and implementation of a strategy for transfer and interim storage of sludges, with or without treatment.* Several programmatic and technical factors will strongly influence the direction and design of transfer and storage, including (i) whether facilities developed for interim storage, treatment and/or packaging of K West Basin sludges will include planning and integration with other site-wide Remote Handled Transuranic Waste (RH-TRU) management needs, (ii) whether interim storage will occur within an existing nuclear facility (i.e., T Plant) or at a new nuclear facility (potentially, using a cask on pad strategy), and (iii) whether treatment (U metal oxidation) and/or packaging for WIPP can be integrated with the transfer and storage container and interim storage system design. Current planning indicates transfer of the retrieved sludges directly from the engineered containers within the basin to STSCs. STSCs then would be relocated to the selected storage location.

c. *Treatment to reduce hydrogen generation to levels acceptable for shipment to and disposal at WIPP.* Currently, this project component is considered part of Phase II. The primary hydrogen generation mechanisms are through radiolysis and spontaneous oxidation of U metal in reaction with water. Hydrogen generation by U metal oxidation has been studied and reasonably well quantified reaction rates and heats of reaction have been determined. The U metal oxidation rate is highly exothermic and strongly dependent on temperature and reactive surface area (i.e., particle size distribution of U metal). However, the amount of U metal in the sludges and the specific hydrogen generation rates (as a consequence of U metal content and U reactive surface area) are not well defined for the sludges, especially for settler tube sludges. A sampling and analysis program is underway to reduce this uncertainty.

Pre-conceptual process development has been initiated for U metal treatment with warm water oxidation (at ca. 80-90 C and ambient pressure) in an agitated reactor as the currently favored treatment approach. Other potential approaches exist that warrant consideration including oxidation during storage in STSCs using heated storage[6]. Important factors in the treatment process selection will be the time frame and location for treatment. An alternatives evaluation and selection process has not been performed to establish the preferred treatment approach. Process development and testing will be required to sufficiently mature the treatment process for

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[6] Integration of treatment and interim storage at T Plant has the potential to significantly accelerate overall project completion if appropriate design and safety criteria can be met.

implementation, including direct measurement of specific hydrogen generation rates at anticipated process conditions.

d. *Packaging of treated sludges after recovery from STSCs and treatment to allow shipment to WIPP.* Currently, this project component also is considered part of Phase II. The Waste Acceptance Requirements for shipment to WIPP include (i) less than 1% free liquids, (ii) hydrogen generation rate, and (iii) curie and fissile gram equivalent (FGE) loading. Uncertainty in the inventory (specific activity and U metal content) associated with the sludges, the packaging approach (e.g., use of an absorbant or grouting), and the waste loading within individual shipping packages are the primary technical contributors to uncertainty in the number of packages (currently assumed to be in 30-gal drums) to be shipped to WIPP. Additional programmatic uncertainties impacting the number of packages and shipments to WIPP are discussed separately below. The current sampling and analysis program for sludges in the engineered containers and planned sampling and analysis program for the settler sludge once retrieved into an engineered container will help to reduce this uncertainty.

e. *Retrieval of KOP material and segregation of spent fuel scrap and debris.* The KOP contents will first be sampled and characterized to determine if existing processing facilities within K West Basin are sufficient to process this stream. Retrieval of KOP material from current locations will be accomplished by vacuuming and/or mechanical means including the potential for tipping into a receiving container within the basin. The current plan is to hydraulically wash the KOP contents, using the existing Primary Cleaning Machine and integrated water treatment system (IWTS), to remove sludge particles less than 600 µm, and spent fuel scrap greater than ¼ inch to the extent practicable. The remaining coarse fraction of the KOP contents will be dispositioned in MCOs. The sludge (< 600 µm) will proceed to the settler tubes to be sampled, characterized, retrieved and dispositioned with the settler tube sludge. From the washing process the course material will consist of two different streams: (i) material larger than 600 µm and smaller than ¼ inch; and (ii) material larger than ¼ inch (in one dimension). Required devices to separate the course material are being designed and tested at MASF. For the course material larger than 600 µm and smaller than ¼ inch, the KOP project plans to separate the metallic U material from the non-U material to minimize the amount of material that will need to be processed as spent nuclear fuel (SNF). The course material fraction larger than ¼ inch (in one dimension) will be visually sorted on a scrap sorter table to separate metallic U fuel scrap from the non-U material. The uncertainties associated with this project component are the inventory of material to be recovered and the effectiveness of the planned mechanical separations. The KOP material characterization, along with device design and testing with K Basin operator participation, are appropriate risk reduction strategies (Sullivan 2008).

f. *Disposition pathways for the Separated KOP material.* The KOP metallic U material is planned to be processed and managed as SNF, loaded into MCOs, transferred to the cold vacuum drying facility (CVDF) and dried, and then the MCOs will be transferred to the Canister Storage Building for interim storage until they can be shipped to a federal repository. The non-U material is planned to be managed with other basin debris as either Low-Level Waste and disposed in the Environmental Restoration Disposal Facility at Hanford or as transuranic waste (TRU), depending on final waste classification. Areas of technical uncertainty with the KOP project component include: (i) the number of spent fuel scrap canisters to be produced; (ii) how dry is dry enough for the SNF scrap; and (iii) the potential for enhanced chemical reactivity of the SNF scrap. Risk reduction strategies are being pursued (see 3.e., above) to help determine the number of MCOs to be produced, which is driven by the uncertainty in inventory estimates of the KOP material and the effectiveness of planned physical separation processes. The smaller particle size range of the KOP material and hydrated compounds more readily retain water and make drying more difficult. The smaller particle size range, and thus the increased surface area to volume ratio, will increase the potential for enhanced chemical reactivity, the pyrophoricity and combustibility characteristics of the KOP material destined for drying, packaging, and interim storage will need to be determined if sufficient information is not available after the KOP material has been characterized.

g. *Inspection and recovery of additional material after debris removal from the basin.* A separate project, the K Basin Disposition Project, is responsible for cleaning and consolidation or removal of debris, residual sludges and fuel scrap from the basin floor. This project will result in deposition of additional sludge onto the basin floor that requires transfer to engineered containers for retrieval, treatment, packaging and disposal. Final inspection of the basin floor may indicate the presence of spent fuel scrap requiring retrieval, washing and disposal analogous to the KOP material. However, the amount of material to be recovered as part of the final basin cleaning has been estimated and included in the project plan.

Phase I and Phase II Project Integration and Selection of an Out-of-Basin Interim Storage and Treatment Locations

RECOMMENDATION 4.

a. An alternatives analysis of sludge treatment and packaging process and facility options should be performed in order to evaluate potential technical, cost and schedule benefits for integration of development of preferred options with the design of sludge storage.

b. A high level review of the relationships between the project timing, processing needs, and facility requirements for the K Basins STP and other Hanford RH-TRU processing needs should be performed to determine if potential benefits can be gained through coordination between projects.

c. More detailed information should be developed and program planning completed to allow for a more thorough alternative facility analysis and selection process, recognizing that the construction of a new facility for treatment, packaging, and shipment of RH-TRU is a programmatic decision that should consider the needs of both the K Basins STP and other Hanford site-wide RH-TRU mission needs.

Discussion. The following provides a summary of the primary basis for selection of interim storage of sludge at the Hanford Central Plateau and the needs for closer integration of STP Phase I and Phase II along with more comprehensive evaluation of the Hanford site facility needs for RH-TRU treatment, packaging and shipment.

a. The initial alternatives analysis (CHPRC 2009a) was performed to compare potential cost, schedule, and technical advantages and disadvantages of process sequences for managing engineered container sludge and settler tube sludge in the K Basin with the primary distinguishing feature amongst options being the (i) the extent of operations within the K Basin versus at a Central Plateau facility (either at T-plant or a new facility), and (ii) the specific sequence of process steps including sludge retrieval, storage, treatment and packaging for disposition at WIPP. As a result, initial cost estimates included notional assumptions about aspects of processing that were common amongst options and did not provide significant detail in process or facility configurations. Results of this initial alternatives analysis indicated a relatively small distinction in life cycle costs for in-basin processing compared to transfer of the sludges to a Hanford Central Plateau facility followed by storage, treatment and packaging at the Central Plateau. However, early transfer of sludges to the Central Plateau facilitates closure of the K Basins consistent with the Hanford 2015 Vision (DOE 2009) for the River Corridor and regulatory preferences (as discussed above). Technical factors did not strongly distinguish between the options at that level of evaluation detail. The initial alternatives analysis then was followed with a more detailed evaluation of options for sludge storage at the Central Plateau, comparing (i) modification and use of the T Plant facility for storage with (ii) design and construction of a new cask on pad storage facility (CH2M HILL Plateau Remediation Company (CHPRC) 2009b). This comparison indicated cost neutrality and a schedule benefit to use of the T Plant facility, rather than construction of a new facility, but only examined costs associated with facility development and operations for sludge storage in STSCs. Still needed is a detailed analysis of integration of storage, treatment and packaging steps, which currently is to be considered in the Phase II alternatives analysis. Potentially, there are life-cycle cost and schedule benefits to integration of design and implementation of Phase I activities with Phase II activities at the Central Plateau, but an integrated alternatives analysis with sufficient detail to distinguish amongst treatment and packaging process and facility options has not been completed.

b. The ETR team has been briefed that the K Basins sludge material accounts for less than 1% by volume, 11% by total Curies (Ci) and 15% by 72-B shipments of the RH-TRU to be generated on the Hanford site. The potential for the facility selected to meet multiple RH-TRU missions has not been evaluated at the site-wide, programmatic level. Insufficient evaluation has been completed to date to select from amongst these options. The relationships between the project timing, processing needs, and facility requirements for the K Basins STP and other Hanford RH-TRU processing needs have not been considered and thus the potential for synergies and cost or schedule benefits that might be gained through project coordination are unknown.

Programmatic Uncertainties that Affect Shipments to WIPP

RECOMMENDATION 5.

a. DOE-RL and WIPP should concur with the assumptions that serve as the planning basis for shipments to WIPP, thus allowing for appropriate project design basis assumptions. The resulting assumptions, requirements and agreements should be formalized through an interface control document.

b. Unresolved issues with respect to waste classification and waste loading assessments should be definitively resolved as rapidly as possible.

Discussion. The number of packages (e.g., 30-gal drums) and shipments to WIPP may be impacted by the resolution of several programmatic issues:

a. The project currently assumes that approximately 50% of the WIPP RH-TRU capacity to ship and receive waste is available to Hanford for shipping of packaged sludge to WIPP, allowing for 125 shipments per year (assuming WIPP capacity to receive RH-TRU at 250 per year or 1 per day). However, packaged sludge from K Basins currently is estimated to be less than 15 percent of the total RH-TRU shipments needed from Hanford to WIPP (see footnote bottom of page 17). The actual number of 72B shipping casks available will be a function of U. S. Department of Energy Office of Environmental Management (DOE-EM) priorities for shipments to WIPP including consideration of competition within Hanford and between sites for shipping of other RH-TRU waste form packages to WIPP. A further consideration will be the availability of RH-TRU disposal panels within WIPP given the anticipated shipping interval and WIPP operations.

b. The classification of sludge removed from the settler tubes has not been fully resolved and agreed to by WIPP. The project currently assumes that the sludge removed from the settler tubes will be classified as RH-TRU but the potential remains for the settler tube sludge to be classified as SNF. Until agreement on sludge classification is reached and regulatory approval is obtained for blending, the project cannot blend sludge retrieved from settler tubes with sludge retrieved from engineered containers because of concern about comingling regulatory waste classifications. Preliminary analysis indicates that blending of settler tube sludge with engineered container sludge will facilitate greater waste loading of RH-TRU waste form packages because settler tube sludge loadings will be limited by FGE while engineered container sludge loading will be limited by waste volume. Initial estimates suggest that this may have the potential to reduce the required number of shipments to WIPP by up to 30%. However, regulatory uncertainty regarding waste classification and acceptability of blending indicates that, at this time, project planning should not (and DOE-RL currently does not) include credit for reducing the number of RH-TRU packages through sludge blending.

c. Dose-to-curie (DTC) analysis requires sufficient knowledge of specific radionuclides present in the final waste form in order to use the dose measurement to calculate the total curies in each waste package from the combined contribution of the radionuclides. The STP has used prior DTC calculations by other sites that indicate a large uncertainty can be anticipated (over 100%) but may be mitigated as additional information is gained regarding the radioisotopic ratios and the final waste form. The DTC analysis will be essential in Phase II operations where the final waste form for WIPP disposal is generated to confirm compliance with applicable WIPP transportation and disposal requirements.

Schedule and Cost Evaluation

RECOMMENDATION 6.

a. A life-cycle cost analysis should be performed consistent with guidelines for performing cost effectiveness analysis provided in OMB Circular A-94 (OMB 1992).

b. A critical path, resource loaded schedule should be developed for Phase I and technology maturation required in advance of implementation of Phase II (e.g., technology maturation needed for retrievals from STSCs, treatment and packaging, as well as in support of Phase I) to provide a foundation for planning purposes and evaluating opportunities for overall project acceleration.

Discussion. The estimates for the basic costs and schedules are reasonable. However, the life cycle cost analysis, as presented by the project team, is incomplete. The analysis identified the expected overall expenditures for each alternative, but did not express those expected future costs in present worth terms before inferring any differences in costs. (The present worth is the standard criterion for evaluating life cycle costs, as prescribed by the Office of Management and Budget and in DOE regulations and cost guides [OMB 1992, AACE 2005].)

The ETR team, using the basic cost estimates and factoring in the uncertainties associated with those estimates, performed its own probabilistic analysis of the life cycle costs of the four leading alternatives: Alternatives 6-T, 6-N, 7-T, and 7-N (see Table 2, below, for definitions)[7]. The ETR analysis suggests that, statistically, there are no meaningful cost differences among those alternatives. A summary chart of those findings are presented below in a box-and-whisker plot format. The box portion of each diagram reflects the expected present worth costs between the 25th and 75th percentiles of the likely distribution of costs. The ends of the whiskers reflect the lower bound and upper bound costs of that distribution. The allocation of costs that comprise the overall cost estimates indicate that only less than 20 percent of the project's total cost is associated with the retrieval of wastes from the K Basin and subsequent interim storage (Phase I). The selection of the sludge treatment process and facilities for treatment, packaging, and loading for shipment to WIPP, which have not yet been determined, represent more than 80 percent of the total project costs (Phase II).

The schedules for each alternative are divided into two phases. Phase I comprises those activities that occur at the River Corridor. Phase II comprises those activities that will occur on the Central Plateau. This division in each alternative's overall project schedule seems to be a sensible approach for showing the project team's emphasis on removing the sludge from the River Corridor as quickly as possible. The overall determinant for completion of the STP mission (and initiation of RH-TRU shipments to WIPP) is the availability of a facility for treatment, packaging, and shipment of RH-TRU, which currently is not available at Hanford.

The schedules for the alternatives, like the basic cost estimates, appear to have been prepared competently. The project activities in the schedules are linked logically in a coherent path that seems to adequately reflect the alternative's project plan from start to finish. The estimated durations for the various activities seem reasonable given the level of uncertainty associated with those activities at the current stage of project development.

[7] The cost evaluation looked only at the Engineered Container / Settler Tube alternatives analysis and did not address the ongoing KOP disposition activities.

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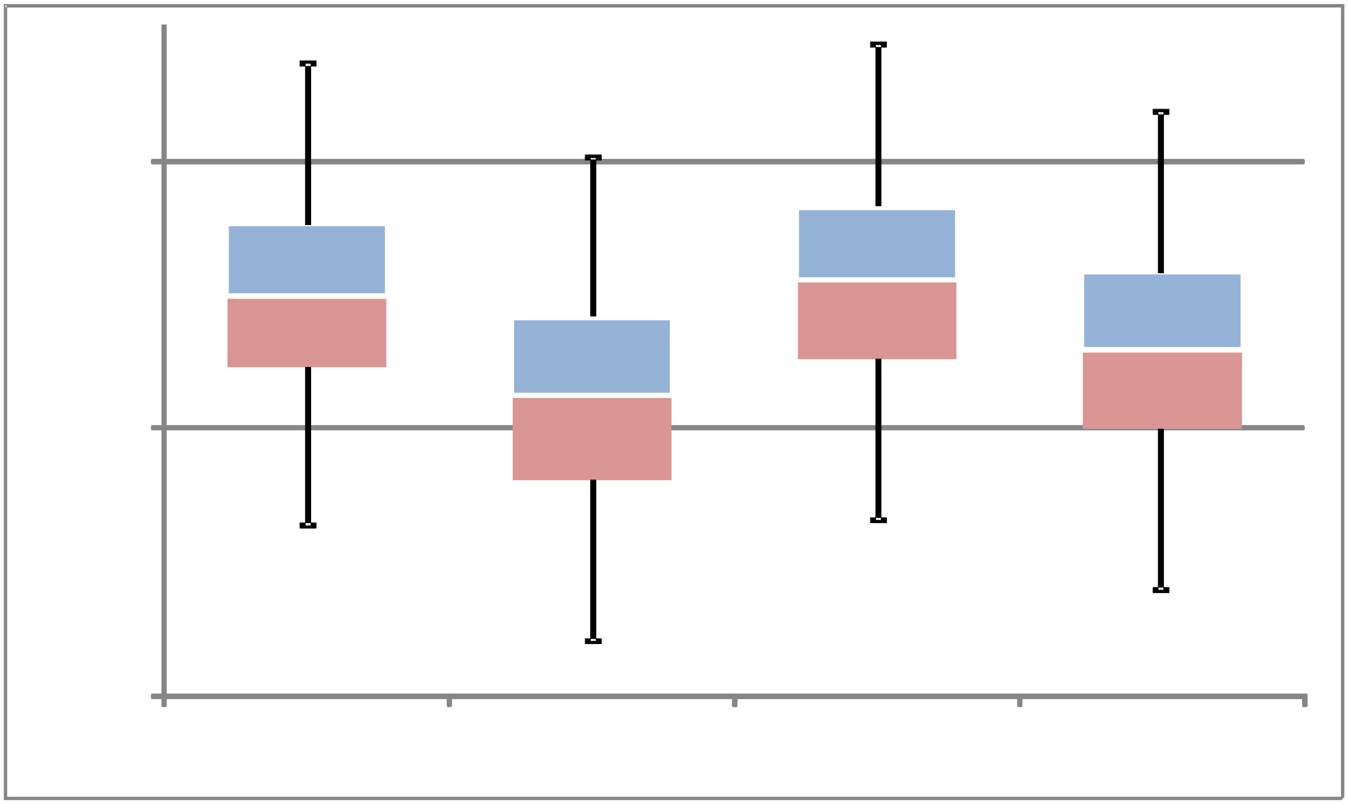

Figure ES-1. Life Cycle Cost Estimates of the Sludge Treatment Project

Nevertheless, the schedules are neither resource-constrained nor fully integrated with events external to the STP. For example, there is a potential for additional sludge to be generated from the clean out of K West Basin that has not been factored in the cost or schedule estimates but are included as part of the project risk management plan. Similarly, there is a potential for a need to recover and treat additional fuel scrap from the basin floor after cleaning and removal of debris. Yet, for alternative analysis purposes, those shortcomings and omissions in scheduling would not likely have a significant effect on the inferences drawn about the preferred alternative. However, a critical path, resource loaded schedule for near term activities and those activities for which a preferred alternative has been selected would provide a foundation for planning purposes and evaluating opportunities for overall project acceleration. Thus, a critical path, resource loaded schedule would be useful for Phase I and also for technology maturation required in advance of implementation of Phase II (e.g., retrievals from STSCs, treatment and packaging).

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External Technical Review of the Hanford K Basins Sludge Treatment Project

External Technical Review Scope

This ETR was requested to address the following overarching questions with respect to the STP for retrieval, treatment, storage and preparation for disposition of sludges and related materials currently stored in K West Basin at Hanford:

- Is a new facility needed? Can the desired results be achieved with a minimum of new construction or is a new facility proposed?
- Why does it take ten years to start shipping treated sludge to WIPP? Why is the time scale the same whether the work takes place at-basin or at the Central plateau?
- Do the advantages of moving the sludge followed by treating and packaging it on the Central Plateau outweigh the advantages of doing all the work at K Basin?

This review focuses on several major areas: project management, technical risks, regulatory risks, system risks, safety risks, and risks associated with expert elicitation. The lines of inquiry that provided a framework for evaluation for this ETR are provided in the review charter (Appendix B).

Background and Summary Description of Sludge Treatment Project

The K Basins STP is responsible for sampling and analysis, retrieval, treatment, interim storage, packaging, and shipping of sludges and related materials currently located within the K West Basin in the 100 Area (along the Columbia River Corridor) at Hanford. The following materials currently present in the K Basin are included to be managed as part of the project: (i) sludge currently stored in engineered containers (engineered container sludge), (ii) settler tube sludge, and (iii) knock-out pot material. Although additional basin vacuuming will occur prior to basin decommissioning activities, the collected material will be either dispositioned as engineered container sludge or fuel scrap. The basic characteristics of each of these waste streams are provided in Table 1, as derived from prior sludge sampling and consolidation activities and best engineering estimates. Additional sampling is in-progress and also supports nuclear material accountability and to provide confirmatory analysis for process development and design.

Table 1. K-Basin Sludge Characteristics (Fluor 2003)

Characteristic	KOP	Settler Tube	Engineered Container
Source	KW* IWTS fuel washing operations	KW IWTS fuel washing operations	KE & KW floors & pits, KE canisters
Dose (R/hr)	10 – 400	10 – 40	1 – 10
Particle Size (μm)	600 < x < 6350 [0.25 in]	< 600	<6350 to submicron
Volume (m^3)	0.3	5.4	23.2

* KE and KW refer to K-Reactor east or west basin, respectively

The composition of the sludge in the engineered containers is primarily iron and aluminum oxides, concrete grit, sand, dirt, paint chips, and operational and biological debris. It also is contaminated with fuel corrosion products and small fragments of metallic U. The sludge in the Settler Tanks ranges in particle size from a few microns to <600 microns. It is expected to be primarily U corrosion products and fission and activation products, with some remaining metallic U. This projected inventory of sludge in the settler tubes is based on previous characterization of sludge samples from fuel canisters and a material balance constructed from data collected during SNF packaging operations (Flour 2001). Settler tube sludge may also contain lesser quantities of iron and aluminum oxides, sand, Grafoil® (graphite gasket material) fragments, concrete grit, dirt, and other operational debris.

Discrete sludge processing functions considered as part of the alternatives analysis for management of engineered container sludge and settler tube sludge are:

- **Sludge Mobilization:** Process that mobilizes and removes the sludge from the storage containers;
- **Pretreatment:** Physical separation of U metal or U material from a sludge stream;
- **Treatment:** A process that reacts U metal for hydrogen mitigation, regardless of whether pretreatment function is applied;
- **Interim Storage:** Storage of the sludge on the Hanford Site as a slurry prior to packaging;
- **Sludge Transfer:** Process that moves sludge between other identified functions
- **Packaging:** Process that incorporates sludge into a waste form suitable for disposal at WIPP;
- **On-site Transportation:** Transportation of the sludge slurry or a solid in a container within the confines of the Hanford Site using existing approved casks;
- **WIPP Certification and Transport:** Certification that the final waste form package meets WIPP transport and disposal requirements, and transport of the waste package to WIPP.

To carry out an alternatives analysis for engineered container and settler tube sludges, the site contractor grouped together functions to form integrated alternatives for sludge processing. Not all of these functions are necessarily needed as part of an individual alternative. For example, if sludge pretreatment to separate U metal is not performed, then the treatment function processes all of the sludge instead of the U metal fraction. Additionally, some or all of these functions considered potentially to be performed at the K West Basin, at the Central Plateau 200 Area , or at facilities located away from the Hanford Site (i.e., off-site).

The alternatives analysis took advantage of the large number of past studies on sludge disposition as a starting point to identify viable technologies, facilities, and transportation methods for accomplishing the required sludge processing functions. Prior studies were a source of the data used in this evaluation. Additionally, new technologies were identified to potentially accomplish the sludge processing functions. At the initial stage of generating and evaluating alternatives, methods were not identified for the sludge mobilization, sludge transfer, and WIPP Certification and Transport functions because those functions are common to all alternatives and do not differentiate among alternatives. Subsequently, specific methods were identified for sludge retrieval and transfer, but the specific methods also did not provide a discriminator between alternatives considered and additional technology maturation needs were identified (CHPRC 2009a). The necessary processing steps, technologies, facilities, and transportation methods were then combined into multiple unique alternatives to potentially accomplish the STP mission, with the resulting set of potential alternatives then reduced to seven representative alternatives. Table 2 summarizes the seven resulting representative alternatives.

The seven alternatives, including the information generated to evaluate these alternatives were reviewed by an Independent Review Committee (IRC) in September 2008. The IRC assessed the alternatives development process and the seven selected alternatives. Besides the IRC, the review included representatives from DOE, EPA, Defense Nuclear Facilities Safety Board (DNFSB) and WIPP. The IRC concluded that the project had followed a sound process for developing these seven alternatives. The IRC then recommended a Rough Order of Magnitude life-cycle cost and schedule analysis and a preliminary Hazards Consideration consistent with expectations in DOE STD-1189-2008 (DOE 2008d) for the seven selected alternatives, which the STP engineering team prepared.

Table 2. Description of Seven Alternatives Initially Identified for Sludge Processing (CHPRC 2009a)

Alternative	Description of Functions
1	• Retrieve sludge from Engineered Containers • Conduct sludge Pretreatment and Treatment in the K West Basin • Transfer the treated sludge as a slurry in the Sludge Transport System (STS) cask to the Central Plateau 200 Area • Interim-store the treated sludge in either T Plant or a new facility on the Central Plateau 200 Area • Package the treated sludge into a final waste form (grout or absorbent) suitable for disposal at WIPP in a new packaging facility located on the Central Plateau 200 Area • Interim store the packaged sludge until containers are packaged for shipment to WIPP
2	• Retrieve sludge from Engineered Containers • Conduct sludge Pretreatment and Treatment in the K West Basin • Package the treated sludge into a final waste form (grout or absorbent) suitable for disposal at WIPP in a new packaging facility located at the K Basin • Transport the packaged sludge in ISCs to the Central Plateau 200 Area for interim storage in a new facility • Interim-store the packaged sludge until containers are packaged for shipment to WIPP
3	• Retrieve sludge from Engineered Containers • Package the untreated sludge into a final waste form (absorbent) suitable for disposal at WIPP in a new packaging facility located at the K Basin • Transport the untreated packaged sludge in ISCs to the Central Plateau 200 Area for interim storage in a new facility • Interim-store the untreated packaged sludge until containers are packaged for shipment to WIPP
4	• Retrieve sludge from Engineered Containers • Package the untreated sludge into a final waste form (grout) suitable for disposal at WIPP using new equipment located underwater at the K Basin • Transport the packaged sludge in the ISCs to the Central Plateau 200 Area for interim storage in a new facility • Treat the packaged sludge to oxidize U metal by heated storage of the waste containers • Interim-store the treated packaged sludge until containers are packaged for shipment to WIPP
5	• Retrieve sludge from Engineered Containers • Package the untreated sludge into a final waste form (grout) suitable for disposal at WIPP using new equipment located above water at the K Basin • Transport the packaged sludge in ISCs to the Central Plateau 200 Area for interim storage in a new facility • Treat the packaged sludge to oxidize U metal by heated storage of the waste containers • Interim-store the treated packaged sludge until containers are packaged for shipment to WIPP
6	• Retrieve sludge from Engineered Containers • Transfer the untreated sludge as a slurry in the STS cask to the Central Plateau 200 Area • Interim-store the untreated sludge in either T Plant or a new facility on the Central Plateau 200 Area • Conduct sludge Pretreatment and Treatment in a new facility located on the Central Plateau 200 Area • Package the treated sludge into a final waste form (grout or absorbent) suitable for disposal at WIPP in a new packaging facility located on the Central Plateau 200 Area • Interim-store the packaged sludge until containers are packaged for shipment to WIPP
7	• Retrieve sludge from Engineered Containers • Transfer the untreated sludge as a slurry in the STS cask to the Central Plateau 200 Area • Interim-store the untreated sludge in either T Plant or a new facility on the Central Plateau 200 Area • Package the untreated sludge into a final waste form (grout) suitable for disposal at WIPP in a new packaging facility located on the Central Plateau 200 Area • Treat the packaged sludge to oxidize U metal by heated storage of the waste containers • Interim-store the packaged sludge until containers are packaged for shipment to WIPP

The preliminary Hazards Consideration (CHPRC 2008a) review included representation from Nuclear and Process Safety, Criticality Safety, Industrial Safety and Hygiene, Radiological Control, Project Engineering, and Fire Protection disciplines and was consistent with the expectations of DOE-STD-1189-2008. This preliminary Hazards Consideration review determined the following:

1. None of the alternatives exhibit a clear, distinct safety advantage;

2. Only safety significant controls are needed (i.e., no safety class controls) for each alternative; and,
3. There is no unique or unanalyzed hazard associated with any of the seven alternatives.

The schedule analysis focused on the critical path of each alternative to remove sludge away from K Basins and the Columbia River. Three alternatives, Alternatives 1, 6, and 7 utilize a two phase approach with transfer of sludge as slurry to the Hanford Central Plateau 200 Area prior to packaging (see Table 2 for details; CHPRC 2009a):

Phase 1 – Removal of sludge and related materials from K Basins, including materials from engineered containers, and settler tubes, on-site transportation and interim storage; and,

Phase 2 – Treatment, packaging, storage, and preparation for shipment to WIPP.

Analysis of these alternatives indicates removal of the sludge from K West Basin five to nine years faster than Alternatives 2 through 5, which package sludge at the K Basins. Thus, Alternatives 1, 6, and 7 are consistent with the DOE and EPA Region 10 objectives to remove the sludge off the River Corridor as soon as possible and achieve the Hanford 2015 vision (DOE 2009) for the Columbia River Corridor, providing comparative benefit to Alternatives 2 thru 5. As currently envisioned, interim storage in the 200 Area Central will be in either T Plant or a new facility. Facilities for treatment and packaging have not been identified.

No formal alternatives analysis was prepared for the KOP material. While disposition of the KOP material will occur during the timeframe that Alternative Analysis Phase 1 activities are implemented, KOP disposition is not considered a part of Phase 1 but occurs concurrently with Phase 1 activities.

Alternatives 1, 6, and 7 were selected by the STP for further evaluation by a Decision Support Board (DSB) based on the analysis discussed above. These alternatives then were developed in greater detail by the STP engineering team prior to the DSB rating and ranking of each alternative. Pre-conceptual designs were developed sufficiently to provide supporting information for an Association for the Advancement for Cost Engineering International Class 4 (AACE 2005) cost estimate (+50%/-20% accuracy range on capital costs) and schedule. At this stage of alternatives development, interim slurry storage at a new facility was compared with interim slurry storage in T Plant for each of the three alternatives (designated "N[8]" and "T" alternatives, respectively), creating sub-alternatives 1N, 1T, 6N, 6T, 7N, and 7T.

Subsequently, five selection criteria were used by the Project for rating and ranking the three alternatives:

Safety: Safety input was provided based on preliminary hazards evaluations. Each of the safety disciplines (i.e., Nuclear and Process Safety, Criticality Safety, Industrial Safety and Hygiene, and Fire Protection) were used to evaluate the three pre-conceptual designs. The safety

[8] Thus, Alternative identifiers ending in "N" indicates that that alternative would be realized through new construction while those ending in "T" indicates the use of T plant.

disciplines used a go/no-go criterion for the alternatives (CHPRC 2009a). It was determined by the Project that each alternative could be configured to adequately control the respective hazards by using well established mitigation methods, and as a result, no discriminators between alternatives were identified (CHPRC 2008b).

Regulatory/ Stakeholder Acceptance: Stakeholder input has been received as public comments from past K Basins remedial action planning in support of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Record of Decision (ROD) (EPA 1999) and ROD amendment (EPA 2005). Since none of the alternatives treat sludge soon after removal from the Engineered Containers, an "Explanation of Significant Differences" or an amendment to the CERCLA ROD will be needed. Development of these documents is achievable within the project schedule.

Technical Maturity: Likely technologies to perform functions were selected based on previous studies and perceived relative cost and/or complexity. The selected technologies were pre-conceptual designs of those likely to be used but definitive selections were not made. The level of technology definition was sufficient to discern primary distinguishing features among process sequence concepts for comparative purposes and initial down selection but not sufficient for final process selection.

DOE-EM guidance on determining technology readiness (DOE 2008a) was applied informally at the pre-conceptual STP design stage to provide a preliminary high-level assessment of technical risk associated with the three alternatives. Representative critical technology elements (CTEs) were identified for the three alternatives, and subject matter experts prepared Technology Readiness Level (TRL) evaluations of the critical technologies using the TRL questionnaires and TRL scale. The TRA evaluation questions included programmatic, technical, and manufacturing criteria. Some non-technical criteria were not considered applicable at this pre-conceptual stage.

Operability and Maintainability including “As Low As Reasonably Achievable” **(ALARA) Considerations:** Operations and maintenance of equipment within the K West Basin must be performed remotely due to the high radiation dose rate from materials stored within the basin. Personnel are required to wear protective equipment such as a breathing respirator, anti-contamination and water barrier clothing, and safety harnesses to avoid falls. Personnel use long-reach tools and hoists to access equipment within the basin. There is limited access through grating to objects within the basin. The approximately 17-foot water depth in the basin provides shielding to reduce the radiation exposure to personnel. The visibility within the basin water can be quickly obscured when performing operating and maintenance activities that disturb materials contained within the basin.

ALARA radiation dose estimates were prepared by K Basin operations personnel for each of the conceptual alternatives. The primary distinction between Alternatives 1, 6 and 7, is that Alternative 1 has more extensive construction and operations within the K Basins.

ALARA, operability, and maintainability considerations for the three alternatives favored minimizing the placement of new equipment and minimizing sludge slurry movement activities within the K West Basin. Alternatives 6T/6N and 7T/7N install less equipment and perform fewer sludge movement activities within the K West Basin than alternatives 1T/1N, since sludge treatment and packaging is performed in a new facility located on the Central Plateau 200 Area .

Programmatic Aspects: Analysis of the programmatic aspects indicate that alternatives 6T and 7T have the shortest duration for Phase 1, which is estimated to be approximately two to three years less than the other alternatives. There appears to be no discrimination between alternatives for life-cycle schedule except that alternatives 7T/7N are complete one year later due to the heated drum storage after packaging to oxidize U metal. The alternatives have similar total life-cycle costs. No differentiation can be made between the alternatives when considering impacts to WIPP or other programs. Integration with other K West Basin activities and T Plant can be managed for all alternatives.

In addition to and consistent with the numerical rating for alternative 6T, the Project Team considers it to have the following advantages:

- Expeditiously reduces the nuclear safety hazard by removal of sludge and more rapid closure of the K Basin.
- Expeditiously reduces environmental risks by moving sludge away from the river, thereby allowing earlier remediation of the chromium plume beneath the basin.
- Earliest possible closure of 100-K operable units as required by environmental and regulatory agreements.
- Does not preclude decision on ultimate disposition of the waste and preserves the option to combine treatment with other required facilities at Hanford.
- Avoids installation and operation of sludge treatment and packaging systems within the difficult operating environment of K West Basin.
- At least five to nine years quicker for removal of sludge from the Columbia River Corridor than any alternative that immobilizes the waste at or near the basin.

Additional Background Material

Hose-in-Hose

A central task in the STP is to retrieve the sludge from the K Basin and move it to whatever the subsequent processing might be. Earlier work requiring similar sludge retrieval employed a technology called "hose-in-hose." The results of using this approach were less than desired primarily due to a lack of understanding of the nature and character of the sludge (DOE 2005). Significant lessons learned from prior hose-in-hose transfers are being applied in this project.

Two-Phase Approach

The primary reason for separating this project into two phases is the key DOE objective of removing the sludge from the K West Basin and Columbia River Corridor as soon as possible. Early removal reduces risks to the environment, allows for remediation of contaminated areas under the basins, and supports early closure of the 100-KR-4 operable unit.

Funding Levels

EM guidance requires STP to stay within existing funding levels and have a high degree of certainty of success (greater than 80%). The current STP five-year (and 10-Year) funding profile cannot support design, construction, and operation of an in-basin treatment and packaging system due to other higher site priorities and continued sludge retrieval and mobilization technical challenges limit its ability to achieve an 80% confidence level of success.

Regulatory Agreements
The EPA and Washington Department of Ecology recently agreed to establish new 100 K Area milestones. These negotiations were done with knowledge of the planned DOE RL two phase approach to treat and package the K Basin sludge—which has regulatory support because of its schedule implications.

Analysis of Primary Alternatives for the Sludge Treatment Project

Primary Alternatives Selection

The seven primary alternatives may be grouped into two broad sludge processing strategies: a) retrieval, treatment and packaging in or near K Basin; verses, b) retrieval, transfer to the Hanford Central Plateau, followed by treatment and packaging as Phase 2. In October 2008, the Project down selected to options 1, 6, and 7 (Figure 1), with concurrence from an IRC and DOE-RL, based largely on a Phase 1 schedule advantage of moving the sludge from K Basin to the Hanford Central Plateau.

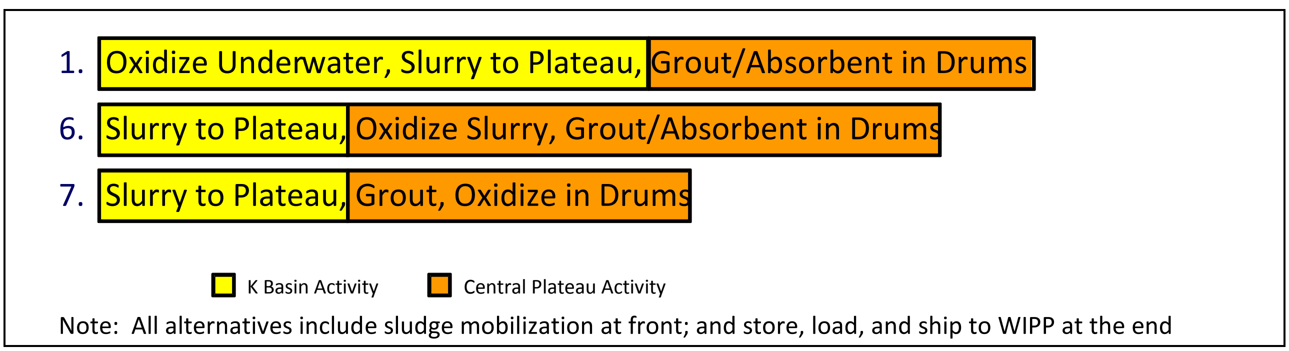

Figure 1. Illustration of activities at K Basins versus the Central Plateau for Alternatives 1, 6 and 7 (CHPRC 2009a).

The required building blocks are similar for all of the alternatives scenarios, with the primary distinguishing features between scenarios being the process sequence and location of process steps. Therefore, the use of first order approximations of the various blocks for alternate selection is reasonable.

Factors that favor the strategy of moving the retrieved sludge to the Central Plateau prior to treatment include:

1) Reduction in environmental risk to the Columbia River by earlier removal of the sludge out of K Basin and off of the Columbia River Corridor (Teynor 2009a, DOE 2009,

Loscoe 1999, Gadbois 2009). There is regulatory preference for these options also because they allow for earlier, comprehensive access to a chromium groundwater plume beneath the K Basin facilities for remediation. This factor was a primary determinant in the selection among alternatives. However, the development of regulatory documentation is achievable for all of the alternatives and was not a discriminator between alternatives;

2) Reduced worker dose (ALARA) and better worker efficiency because of sludge treatment and packaging in remote handled facilities rather than in the K Basin itself. Equipment, debris, etc. that breaks the water surface during operation within K Basin has the potential for release of airborne radioactivity, and therefore K Basin is classified as an Airborne Radioactivity Area. The Airborne Radioactivity Area working environment requires that all workers wear anti-contamination clothing and respiratory protection. In addition, K Basin workers use long-reach tools and remote cameras (sludge suspension in the basin water during in-basin operations obscures vision) to conduct work below the water surface. Based upon the constrained operating environment, the project estimates it is approximately ten times more difficult and time consuming operationally within K Basin as opposed to a purpose built hot-cell facility (Bragg 2009);
3) Prior experience from retrieval and transfer of sludge from K East Basin to K West Basin and incorporating lessons learned provides greater technical maturity for retrieval and transport of sludge as opposed to processing of sludge (i.e., in-basin treatment of sludge will require more technology maturation delaying sludge removal from the basins); and,
4) Improved knowledge of sludge inventory and composition before processing, which will allow for development and validation of the necessary suite of sludge simulants.

Factors that favor retrieval and treatment in or near K Basin include:

1) Potential for the project to stagnate after transfer of sludge to the Central Plateau and incurring additional technical difficulty in future material processing because of sludge oxidation and settling. Interim storage of the sludge may allow for compaction of the sludge creating a rheological state that is more difficult to mobilize and retrieve and most likely would include another sampling campaign to verify chemical, physical, and rheological state of the sludge; and,
2) Potential for earlier oxidation of the U metal contained in the sludge.

In-basin treatment was evaluated as part of Alternative 1. No successful in-basin packaging systems have been developed or demonstrated. Thus, to complete all necessary operations in or near the K Basin would likely require construction of a new packaging and storage facility near the basin or extensive time for technology maturation.

Following initial alternatives evaluation, a more detailed evaluation and comparison was completed of interim storage at T Plant versus a new cask on pad storage facility (CHPRC 2009b). The initial alternatives analysis recommended interim storage of the K Basin sludge at T Plant. However, the DSB identified potential risks with interim storage in T Plant due to the facilities age and potential to not be able to be seismically certified for this use. The subsequent more detailed analysis of interim storage found these concerns to be low risk based on review of earlier seismic analyses and prior preparation of several cells within T Plant for sludge storage (several cells had been prepared for storage of sludge from K East Basin but were not used for this purpose). The most significant identified T Plant upgrades are facility modifications, including cell cleanout and the installation of liners and racks within process cells, to support sludge storage (CHPRC 2009b). The ETR team believes there might also be the potential to integrate retrieval, shipping, oxidation and possibly even final packaging of the K Basin sludge into a single canister design and suggests further consideration of this approach.

The implementation of a new cask on pad facility would require the design of new storage casks to contain the STSCs along with new safety and environmental analyses. In contrast, use of the T Plant can take advantage of prior safety and environmental analyses completed in conjunction with earlier plans for sludge storage at T Plant and therefore only require updating for the revised mission. Furthermore, implementation of storage at T Plant can be achieved more rapidly because of less design and construction work. The primary risk associated with STSC storage at T Plant is the durability of other on-going missions for T Plant. The current comparative evaluation assumes that the costs attributed to the STP are only the incremental costs associated with the sludge storage and that the primary operating and maintenance costs for T Plant are paid for by other projects.

The comparison of the alternatives evaluation for Alternatives 1, 6 and 7 is summarized as follows. The primary distinguishing features favoring Alternatives 6 and 7 over Alternative 1 are (i) the earlier removal of sludge from K Basins and the Columbia River Corridor, allowing attainment of Hanford restoration and regulatory goals, concurrent with reducing the environmental risk to the Columbia River, (ii) allowing more time for treatment and packaging process development, and (iii) easier operability, maintainability and implementation because of fewer operations within the K Basins where activities likely pose greater radiation exposure hazards and physical constraints. Preliminary analysis also suggests that Alternative 6 (treatment prior to packaging) may be favored over Alternative 7 (packaging followed by in-drum treatment using heated storage) because of greater reliability in implementation, however, more detailed analysis is needed for process selection and design as part of Phase II.

Primary Project Components and Technical Risks

The STP's current planning basis is to perform the project in two distinct phases. Phase I is to effect the mobilization, and transport of the sludge to the central plateau for temporary storage and Phase II is to process the sludge into an acceptable waste form for ultimate disposal.

Technical process steps are logical and the project recognizes the key ones. Risks associated with technology development are recognized. Extensive technology maturation (design, development, testing) is needed for major process steps before implementation.

Phase I Sampling and Analysis

The project is to handle the residual sludge remaining in the KW Basin following fuel washing and packaging, and basin cleanout, which is found in three separate streams: engineered containers, settler tubes, and KOPs. Each may have different characteristics and will need to be sampled, analyzed and characterized. The project is currently sampling engineered container sludge and plans to sample or characterize the others streams in the future. Sampling and characterization needs for the sludges from the engineered containers and settler tubes are specified in a Data Quality Objective document and characterization will include identification of fissile material concentration (for nuclear safety and safeguard and security requirements), and physical properties (particle size, density, sludge shear strength, etc) to support design of the sludge retrieval and transport system. A separate data quality objective document currently is under development for establishing the characterization plan for the KOP material and therefore laboratory characterization needs for this material are uncertain.

The review team considers the sampling to be critical to system design for Phase I (retrieval and transport) and for Phase II (processing and packaging) and should be a high priority activity for all three waste streams. Sufficient sample volumes should be taken to allow for warm water (or an alternative) oxidation testing, to validate assumptions regarding hydrogen generation rates and processing times needed to meet subsequent requirements for packaging, transport and acceptance at WIPP.

Engineered Container Retrievals

Engineered container sludge represents the majority of the sludge to be handled and is primarily the result of cleanout of the basins (KE and KW), containing a varied mixture of concrete particles, sand, corrosion particles, and small debris. The containers are large rectangular boxes roughly 12’Lx5’Wx13’H with an egg crate configured bottom. The project intends to retrieve the sludge from utilizing either a direct suction pump or a HydroLance (developed with EM-20 funding) to lift the contents as a slurry for transfer to a loadout system for placement in the transport and storage containers. Previous experience with removal of containerized sludge (bottom retrieval) in K East Basin proved that the sludge can be very difficult to mobilize. The project is pursuing a testing program to assess technologies to effect this retrieval and has encountered some difficulty with performance of the direct suction pump. The review team considers the mobilization of the sludge to be a significant challenge and that sludge characterization coupled with simulant development and mobilization testing should be of high priority to reduce uncertainties.

Settler Tube Retrievals

Settler tubes are a component of the IWTS and are designed to collect the sludge that passed through the KOPs and strainers and consists of sludge particles smaller than 600 microns. The tanks are horizontally oriented and nominally 20” in diameter with smaller pipes entering on the ends. Solids settled as the slurry flowed from the pipe to the tanks. The project plans to retrieve the sludge by inserting an integrated high pressure sprayer and suction device into the tanks via one of the piping penetrations. The sprayer will mobilize and the suction head will remove the resulting sludge/water slurry. Testing is currently underway and will be validated with simulants reflecting the existing results from characterization of KE and KW Canister sludge samples, which is analogous to the sludge contained in the settler tanks.

Knock Out Pot Washing, Separations and Retrievals

KOPs, also a component of the IWTS, are designed to collect larger particulates that pass through the roughing screen at the Primary Cleaning Machine (PCM) during the fuel cleaning process. The larger particulates were to fall out at the KOP while the smaller particulates (<600 micron) were to pass on to the settler tubes. This process may not have performed as expected and the KOPs may contain a mixture of large and small particulate. The opening and characterization of the KOPs has yet to be completed, therefore the material separation strategy is not well defined and material characteristics are not yet known.

The project has grouped the IWTS Strainer Basket material and PCM canister material that resulted from fuel cleaning operations, into the same category of KOP material, which is currently planned to be dried and packed into MCOs for storage with the packaged spent fuel and fuel fragments ultimately destined for deep geologic repository.

The review team considers the characterization and separation strategy to be a significant unknown and that the characterization of the different components of the KOP stream to be vital to the design of the removal/treatment system, determination of possible increased chemical reactivity, and subsequent SNF drying campaign. The project will need to determine how dry the KOP material must be to prevent later issues with container pressurization and corrosion [ASTM C1454 - 07, ASTM C1553 – 08]. In addition, the metallic U corrosion due to storage in water coupled with increased surface area may have enhanced the chemical reactivity of the metallic U creating U hydride particulates and/or inclusions in the U metal matrix.

STSC Design

Sludge will need to be removed from STSCs after extended storage and settling periods, which may result in increased sludge cohesion resulting from settling and aging processes. In addition, *in-situ* treatment (oxidation of U metal) through heated storage of STSCs is a potential treatment process option. *In-situ* treatment would require consideration of increased hydrogen removal rates and possibly agitation of particles to disengage hydrogen and oxidation rinds. Demonstration is needed of the STSC design using appropriate chemical, physical and rheological surrogates for sludge removal after settlement as well as in-situ treatment, if in-situ treatment is considered likely to be a viable option.

General Phase I Issues and Technical Risks

The sludge is found in three separate streams; engineered containers, settler tubes and KOPs. Mobilization, transfer and treatment of the sludge will present challenges. Knowledge of the material physical and chemical characteristics and behaviors of the sludge is necessary to support the design and manufacture of the systems to be used for sludge transfers and processing. Due to the hazardous (radiological, toxicological) nature of the sludge, testing of technologies to be utilized in remediation of the sludge must be conducted with simulants. Development of simulants that adequately mimic the behavior of the actual sludge is critical to the proof of concept for the technologies selected.

Hydraulic retrieval of the sludge from the engineered container and settler tanks poses unique challenges to system engineers. Previous movements of the sludge from K East Basin to K West

Basin proved to be difficult and time consuming. The sludge behavior and characteristics challenged the technologies used to perform that transfer.

The technologies selected for sludge retrieval, some of which are at a low level of maturity, are to be tested on simulated waste material. The project is using MASF for testing of procured equipment and evaluation of its performance with simulated waste. The technology development planning recognizes the needs for full scale testing of most steps, for multiple simulants to duplicate the wide diversity of feeds, and for in process sampling and feed back for control and process adjustment. In this way, they are avoiding several pitfalls suffered by other projects (i.e., adopting technology with inadequate testing specific to the problem to be addressed) and thus learning from previous experience. Care should be taken that design progression does not out strip development and demonstration needs.

The review team recognizes and agrees with the project's prioritization of the characterization of the sludge and development of adequate simulants for testing. Development of adequate simulants that mimic the characteristics of the sludge is critical to the testing and evaluation of technologies to be used in the project for the handling and processing of the basin sludge. The team agrees that rigorous testing of the technologies at the MASF facility is important, but that acceleration of activities should be considered in an effort to reduce the testing schedule duration and allow movement of the sludge from the basin in an expedited manner. MASF provides a valuable resource for testing retrieval and treatment technologies, as well as for operator training, and therefore should remain available during Phase I and during Phase II process maturation and active operations. In addition, the STP is conducting full-scale demonstration of prototypical equipment in the KW Basin using actual KOP materials to refine designs and operations. The STP also is evaluating conducting similar full-scale demonstrations for retrieving and transferring engineered container sludge.

Phase II Components and Technical Risks

The STP current planning basis is to perform the project in two separate phases. Phase II is to store and then process the transported sludge into an acceptable waste form for disposal. The ultimate disposal pathway for the engineered container and settler tube sludge is currently planned to be as RH-TRU and is to go to the WIPP. The STP planning basis to perform the project in two separate phases provides for removal of the sludge from the river corridor as quickly as possible in Phase I, to allow for Decontamination and Decommissioning of the K Basin facility, while allowing more time to develop the treatment technology for oxidizing and stabilizing the sludge into the final waste form in Phase II.

The review team is concerned that the separate phasing of the project may not only result in the possible curtailment of the Phase II work but also may cause the sludge to take a form in the interim storage containers that may compound the problem when Phase II work is initiated. Mobilization and transfer of the sludge into interim storage containers for an extended period may result in the sludge developing properties making it difficult to retrieve when necessary for processing. Phase I testing should consider these possibilities to prevent problems during Phase II. Sampling and analysis of the separate waste streams is critical to support Phase I testing in mobilization and transfer and Phase II interim storage mobilization, transfer, and processing.

The sludge, as found in the basins, contains U metal particles which may react with the water in the sludge and generate hydrogen gas above acceptable levels to meet WIPP acceptance/shipping requirements. The project currently plans to treat the sludge to react the U metal particles in a controlled manner to significantly reduce the hydrogen gas generation rate. However, a specific technology has not yet been selected.

The review team is concerned with the separation of the STP into two phases and the selection of the warm water oxidation method for treatment of the U metal in the sludge. The distinct separation of the project phases provides for focused effort to reduce the schedule duration for removal of the sludge from the river corridor. However, once that significant risk driver is mitigated, Phase II work could potentially be curtailed, delaying the processing of the sludge to its ultimate disposal form. Phases should be closely coupled to provide for development of an oxidation treatment process during Phase I such that a system is identified and proved to perform the processing of the sludge to final waste form well before Phase II is scheduled to begin. Sufficient maturation of processing steps for Phase II should occur either prior to or in conjunction with sludge transfer under Phase I to insure compatibility of Phase II processing with the STSC design and interim storage configuration. Process control issues including maintaining temperature control and prevention of foaming during oxidation need to be addressed. Alternatives to the baseline oxidation method should also be evaluated during Phase I including the potential for in-situ treatment during storage (e.g., heated storage to oxidize U metal possibly followed by addition of a solidification agent and disposal in the storage container). If the settler tube sludge is determined to have much lower hydrogen gas generation rates and is more rapidly treated (if necessary) than the sludge currently in engineered containers, a separate treatment and packaging pathway may be appropriate for settler tube sludge. A detailed technical maturation plan, identifying technical issues, resolution strategies, schedule, and resource allocations should be developed.

The interim storage of the containerized sludge removed from the K Basin is currently planned to be at T Plant, an existing facility that has been modified to receive similar containers for storage, although further modifications to T Plant would be necessary for the proposed interim storage mission. Phase II processing currently is planned to require the construction of a new facility to provide for the retrieval of the sludge from interim storage containers to the final disposal form. The ETR team suggests evaluating whether the simplification is possible by performing interim storage, treatment (i.e., through heated storage) and possibly even stabilization of sludges in the STSCs. However, this may require design and testing of STSCs to facilitate such processing prior to retrieval of the sludges. In addition, Hanford has many different transuranic waste (TRU) forms that will require remote handling for disposal, with the STP project representing less than 15% of the total RH-TRU 72B cask shipments from Hanford to WIPP (WIPP 2006)[9]. An integrated facility to handle all RH-TRU should be considered as the various waste forms are assessed for treatment.

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[9] The current working inventory estimates for RH-TRU generated from the Hanford Site (M-91 Project Management Plan (draft)) are ~3,082 cubic meters of waste volume, ~287,000 Ci, and, ~6,767 RH-72B Cask shipments to WIPP. K Basin estimates are ~29 cubic meters, ~33,000 Ci, and ~1000 RH-72B cask shipments to WIPP. Thus, K Basin represents <1% of the waste volume, ~11% of total Ci, and ~14% of RH-72B cask shipments.

Phase II processing of the K Basin sludge is currently planned to require the construction of a new facility; similarly, the integration of the facility for treatment of the sludge as part of the STP project with the facility needs for the other Hanford RH-TRU waste forms should be evaluated.

WIPP Requirements

Hydrogen Gas Generation Limits

The WIPP has established criteria for the packaging and transportation of RH-TRU to WIPP (DOE 2006). These criteria help ensure waste received and emplaced at WIPP meet applicable federal and state requirements. The criteria include, among other requirements, waste characterization requirements (DOE 2003), wattage limits, restrictions on prohibited items and pyrophoric material (e.g., U metal), FGE, and the flammable gas limit. Of particular interest to the K Basin project is hydrogen gas generation from both chemical oxidation and radioloysis. Significantly, the hydrogen gas generation from chemical oxidation of U metal (Delegard 2008) in the K Basin sludges needs to be extinguished to a rate at or below the limit set forth in the Remote Handled Transuranic Waste Content Codes for this particular waste type and final waste form (DOE 2008b). Since the final waste formulation and packaging has not yet been established, pending future waste analyses only the basic limiting criteria can be stated, such as, the flammable gas for the 72-B cask (5 volume percent (5 vol.%)) and the FGE limited of 315 for the 72-B cask.[10]

The primary source of hydrogen gas in WIPP's calculations has been based on radiolysis; however, the potential for heat and hydrogen gas generation from chemical oxidation of U metal will need to be accounted for (or added to) in WIPP's calculated wattage and analytical gas generation limits. As a result, the 72-B cask and WIPP acceptance limits for the amount of hydrogen gas generated from the chemical oxidation of U metal in the final waste form to be shipped to WIPP will require oxidation of the U metal to meet WIPP RH-TRU Waste Authorized Methods of Payload Control transportation requirements for the 72B cask and WIPP's RH Waste Acceptance Criteria (Delegard 2008). The RH-Waste Acceptance Criteria incorporates the WIPP Safety Analysis requirements. In order to meet the requirement of less than 5 vol.% flammable gasses (from both radiolysis and oxidation) in the headspace space of the sealed 72-B cask over an established time period, the STP is looking at various methods to oxidize the U metal in the sludges safely, efficiently, and effectively (Mellinger 2004).

[10] Section 5.0, *Gas Generation Requirements*, of this document states the following: "[f]or any package containing water and/or organic substances that could radiolytically generate combustible gases, determination must be made by tests and measurements or by analysis of a representative package such that the following criterion is met over a period of time that is twice the expected shipment time (defined in Appendices 2.3 and 2.4 of the RH-TRU Payload Appendices1): The hydrogen generated must be limited to a molar quantity that would be no more than 5% by volume of the innermost layer of confinement (or equivalent limits for other inflammable gases) if present at standard temperature and pressure (i.e., no more than 0.063 gram-moles/cubic foot at 14.7 pounds per square inch absolute and 32°F). The gases generated in the payload and released into the RH-TRU 72-B IV cavity shall be controlled to maintain the pressure within the IV cavity below the acceptable design pressure of 150 pounds per square inch gauge."

At present, work at the Pacific Northwest National Laboratory has and continues to be conducted on understanding the specific nature of U oxidation in K Basin sludges (Delegard and Schmidt 2008). Because of the range of the U metal particles, from a few nanometers to less than 6350 microns (1/4”) in size, the time required to oxidize the larger particles sufficiently to meet the hydrogen gas generation limit has been determined to be the rate-limiting step. Pacific Northwest National Laboratory is also conducting research on the “Use of Nitrate, Nitrite, NoChar®, and Phosphate to Mitigate Hydrogen Generation from the Reaction of Water with Uranium Metal in K Basin Sludge” (Delegard 2009). As a result, the STP expects to conduct some type and/or degree of U metal oxidation in Phase II of the K Basin sludge treatment in order to produce a WIPP acceptable waste form that can be transported in the 72B cask.

Regulatory Designation of Settler Tube Sludge

At present, because of the WIPP compliance recertification application, DOE and the contractor have made the decision and have gained the concurrence of the EPA, that the Settler Tube Sludge waste type may be determined at a future date, depending on additional data, to be TRU waste (Goldstein 1999). However, until such a determination is made, DOE has agreed to keep such sludge waste separate and not mix it with Containerized Sludge. If the Settler Tube Sludge is determined to be TRU waste then operational efficiencies may be possible by the mixing of volume-limited engineered container sludge with FGE limited Settler Tube Sludge; thus, yielding a mixture that will generate fewer drums in total than the total number of drums generated from the containerized portion plus the number of drums generated from the Settler Tube Sludge. The mixing of the two sludges has been estimated to decrease the total number of drums by 30 percent to approximately 2,000 drums. However, the Carlsbad Field Office strongly cautions against blending of the different sludge types because of regulatory uncertainty (Nelson 2009). Thus, the Review Team recommends against planning at this time for improved efficiency through this blending approach, which is consistent with the current DOE-RL planning basis.

Transporting Packaged and Certified K Basin Sludge to WIPP

The STP made a best engineering judgment evaluation regarding the availability of the five (5) 72-B Casks now built and certified for WIPP RH-TRU waste form shipments and determined that no more than 50 percent of the casks would be available to ship K Basin RH waste to WIPP. This translated into about 125 casks being available per year for shipping treated and certified RH packages to WIPP, according to the Sludge Treatment Project. Based on the Project’s current drum generation numbers of about 3000 drums (3 drums per 72-B shipment) it results in about an eight (8) year shipping campaign.

The STP currently expects to begin shipping to WIPP in approximately 10 years, assuming the Phase 2 facilities are designed and deployed concurrent with the Phase 1 removal of sludge from the KW Basin. It is known to the STP that other DOE sites may also be shipping RH waste to WIPP during the time the Project expects to be shipping its waste to WIPP. In addition, the STP is estimated to account for less than 15 percent of the total Hanford RH-TRU 72-B cask shipments to WIPP[11]. Therefore, the Project assumption that 50% of the available 72-B casks would be available for shipment of packaged sludge from the K Basins is only a first order approximation. The STP also realizes that fewer or more casks may be available depending on the needs and priorities at other sites in the complex. The eight (8) years' shipping schedule can be reduced in half if all the 72-B casks are made available to ship the 3000 drums of K-Basin sludges (Riviera 2009).

The Project, based on discussions with another site and WIPP, has conservatively set a 100% error on the DTC measurement until other information becomes available or actual data is found to reduce the error. The project has set the target limit for each 72-B cask at less or equal to 147 FGEs, which translates into about 49 FGEs per drum including the error factor. The Project has set a 20% process error, thus reducing the Project's operational limit to approximately 40 FGEs per drum for Settler Tube Sludge. The Engineered Container Sludge is volume limited to approximately 20 liters per 30-gallon drum.

Other efficiencies, such as increased waste loading per drum, increased accuracy, and a decrease in uncertainty in DTC measurement, along with the use of the 55-gallon drum instead of the 30-gallon drum have the potential, according to the STP, to reduce the total number of drums that will be generated and shipped to WIPP to as low as approximately 2000. Other less probable efficiencies could further reduce the number of drums by another 200 to 300 drums – resulting in approximately 1,700 drums. A realistic estimate of the number of drums to be generated is between 2,000 and 3,000.

[11] The total Anticipated Volume of RH-TRU waste from the Hanford site (i.e. Hanford (Richland-RL) + Hanford (River Protection-RP) is 1.43E+04 cubic meters. The final waste form volume of the K Basin engineered container and settler sludge is estimated to be ~900 cubic meters. Therefore, the K Basin engineered container and settler sludge, in final waste form, is ~6.3% of the total anticipated volume of RH-TRU waste from Hanford site (Johnson 2009).

Cost and Schedule Analysis

Cost Estimates

The project team's estimator followed generally accepted cost estimating techniques and methodologies in preparing the estimate. Those techniques included parametric cost estimating relationships, specific analogy, and expert opinion — all appropriate for estimating costs of the alternatives at their current stage of development. The underlying assumptions for the estimates are consistent, coherent, and well documented. The accuracy levels of the estimates are also reasonable for this stage of the project development.

Life Cycle Cost Analysis

While the base cost estimates are reasonable, the life cycle cost analysis is incomplete. It does not adequately reflect the value to the Government of the expected future costs, which should be calculated in present worth terms[12] (10 CFR 436, DOE 1997) Instead, the analysis presents estimates of total expenditures for each alternative. While those expenditure estimates may be helpful for assessing budget requirements, they are not useful for drawing economic or financial inferences about the relative merits of the alternatives.

In its efforts to assess the project team's claims about life cycle costs, the ETR team performed its own life cycle cost analysis of the two leading alternatives: Alternatives 6 and 7. The ETR team used the cost estimates and schedules for the basic activities as presented in the Alternatives Analysis report plus the amended cost estimates in the STP Phase 1 Sludge Storage Options report. It modeled those costs over the project lives using probabilistic methods to account for uncertainty. It then calculated the present worth of each alternative's pattern of expected annual flows using techniques consistent with those prescribed for performing cost effectiveness analysis in OMB Circular A-94 (OMB 1992).

For construction projects, the team assumed accuracy levels ranging from 50 percent over the most likely value to 20 percent below the most likely cost. This accuracy range is consistent with the recommended range for feasibility studies by Association for the Advancement of Cost Engineering International (AACE 2005).

For cost activities that were estimated as a percentage of an underlying cost activity (such as the cost of design of a construction project), the team assumed accuracy levels ranging from 20 percent above the expected rate to 10 percent below the most likely rate.

For other project cost and ongoing operating costs, the accuracy levels ranged from 20 percent over the most likely cost to 20 percent below the cost.

The team used two different inflation factors. For construction escalation, the team used a rate characterized by a distribution with a mean of 3.5 percent and a standard deviation of 0.5

[12] The cost evaluation looked only at the EC/ST alternatives analysis and did not address the ongoing KOP disposition activities.

percent. For all other costs, the team used a general inflation rate characterized by a distribution with a mean of 2.5 percent and a standard deviation of 0.5 percent.[13]

For discounting future cash flows, the team used a discount rate of 4.7 percent — the prescribed rate in OMB Circular A-94 (OMB 1992).

The ETR team's estimates are presented in Table 3 and Figure 2.

Table 3. Present Worth Costs of the Alternatives (Dollars in Millions)

Alternative	Present Worth Costs	
	Mean Value	**Standard Deviation**
Alt. 6-T	$800	$20
Alt. 6-N	$781	$22
Alt. 7-T	$803	$21
Alt. 7-N	$789	$22

Figure 2 displays box-and-whiskers diagrams of the present worth costs for each alternative. The box portion of each diagram reflects the expected present worth costs between the 25th and 75th percentiles of the likely distribution of costs. The ends of the whiskers reflect the lower bound and upper bound costs of that distribution.

A statistical analysis of the four cost life cycle cost estimates suggest that, in the aggregate, there are no substantial cost differences between any of the alternatives.

The ETR team also examined the costs at one level of detail below the aggregate level. To do that, the ETR team aggregated costs in five broad groupings: retrieval (including transferring the retrieved sludge to the designated storage configuration); storage; treatment and packaging; load-out of the RH-72Bs; and other operating costs. The summary findings of those costs are presented in Table 4. The relative proportion of each activity's cost with respect to the overall cost is displayed in Table 5 and presented graphically in Figure 3. These figures make readily apparent that only less than 20 percent of the project's total cost is associated with the retrieval of wastes from the K Basin and subsequent interim storage (Phase I). The selection of the sludge treatment process and facilities for treatment, packaging, and loading for shipment to WIPP, which have not yet been determined, represent more than 80 percent of the total project costs (Phase II).

[13] The construction cost escalation factor was derived from research performed for DOE's Office of the Chief Financial Officer in late 2008 that led to Department-wide guidance for construction escalation factors. The general inflation rate is derived from historical data of the Gross Domestic Product Implicit Price Deflator over the past 25 years (http://research.stlouisfed.org/fred2/series/GDPDEF/downloaddata?cid=21).

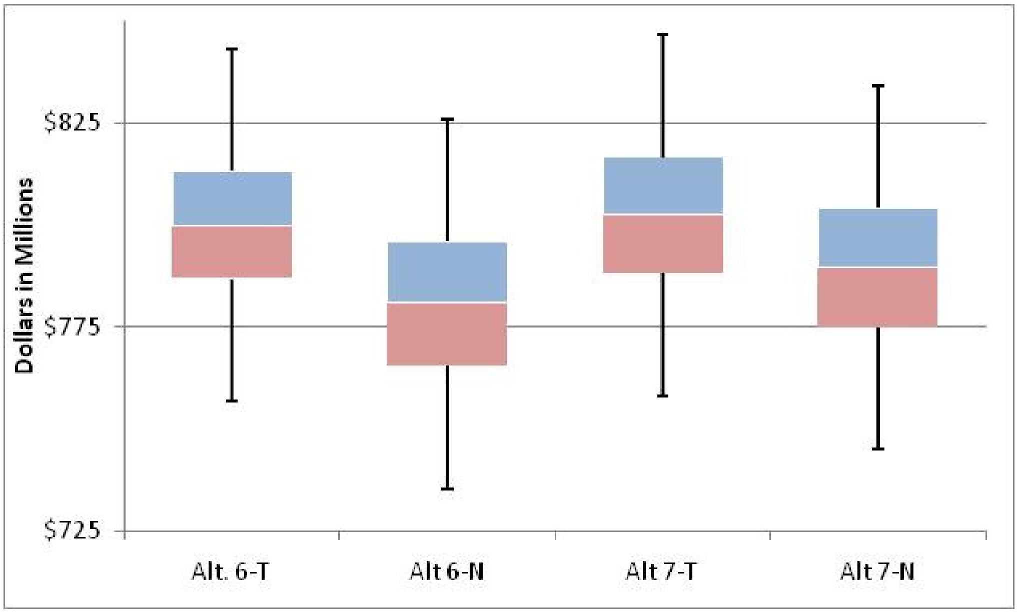

Figure 2. Present Worth of Expected Costs and Projected Funding Profile.

Table 4. Present Worth Costs of the Alternatives – Arrayed by Activity (Dollars in Millions)

	Alt. 6-T	Alt. 6-N	Alt. 7-T	Alt. 7-N
Retrieval	$132.1 (+/- $6.5)	$82.4 (+/- $3.3)	$133.1 (+/- $6.4)	$82.4 (+/- $3.3)
Storage	$10.5 (+/- $0.6)	$14.7 (+/- $0.7)	$10.5 (+/- $0.6)	$14.7 (+/- $0.7)
Treatment	$336.7 (+/- $14.0)	$310.1 (+/- $14.1)	$326.2 (+/- $14.7)	$306.6 (+/- $13.9)
Load-out	$223.9 (+/- $8.6)	$224.5 (+/- $9.1)	$236.1 ($8.7)	$236.4 (+/-$8.8)
Other operations	$96.7 (+/-$8.0)	$149.3 (+/-$12.6)	$96.7 (+/-$8.0)	$149.2 (+/-$12.3)

Table 5. Proportion of Relative Present Worth Costs by Activity

	Alt. 6-T	Alt. 6-N	Alt. 7-T	Alt. 7-N
Retrieval	16.5%	10.6%	16.6%	10.4%
Storage	1.3%	1.9%	1.3%	1.9%
Treatment	42.1%	39.7%	40.6%	38.8%
Load-out	28.0%	28.7%	29.4%	29.9%
Other operations	12.1%	19.1%	12.0%	18.9%

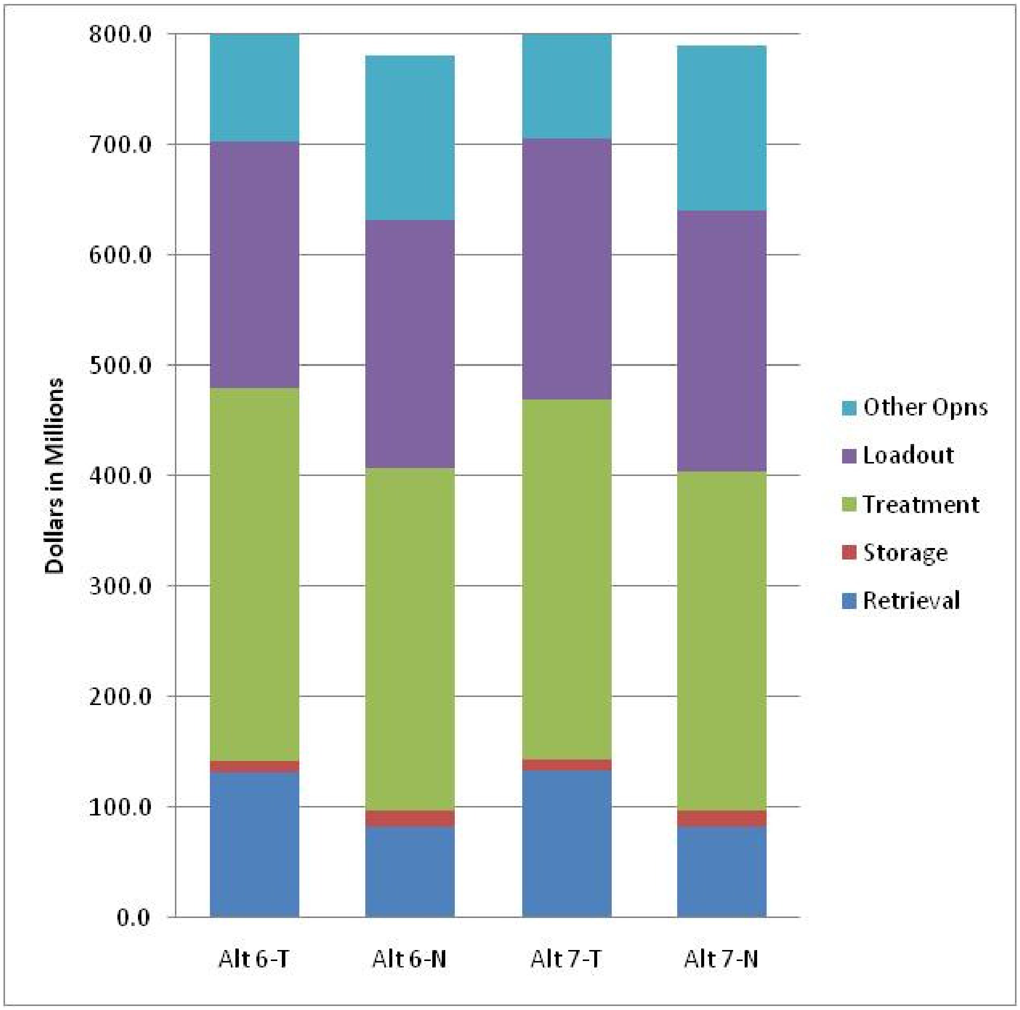

Figure 3. Present Worth of Expected Costs of Activity Groups within each Alternative.

The two major differences in costs among the activity groups are in “retrieval” and “other operations.” In the retrieval grouping (as the ETR team defined it), the primary cost difference between the T building and new building alternatives is in the cost for transporting STSCs to the new central plateau packaging facility and transferring them to the established storage configuration. In the other operations category, the difference in costs is in the cost for performing ongoing “safe/compliant operations” on the plateau. Given that the estimates for ongoing operations are parametrically derived and are functions of how long “ongoing” operations will continue once the storage and packaging facilities are brought on line, these estimates will need to be closely monitored and updated as the project schedules mature.

Risk Analysis

In an alternatives analysis (at the Critical Decision-0/Critical Decision-1 stage), risks are not typically considered in the project cost and schedule estimates. However, the alternatives analysis should identify and compare the risks associated with each alternative, along with the life cycle costs (DOE 2008c). The project team complied with that requirement with its thorough identification and methodical comparison of the associated risks.

Schedule

The schedules for each alternative are divided into two phases. Phase I comprises those activities that occur at the Columbia River Corridor. Phase II comprises those activities that will occur on the Central Plateau. This arbitrary division in each alternative's overall project schedule seems to be a sensible approach for showing the project team's emphasis on removing the sludge from the River Corridor as quickly as possible. The overall determinant for completion of the STP mission (and initiation of RH-TRU shipments to WIPP) is the availability of a facility for treatment, packaging, and shipment of RH-TRU, which currently is not available at Hanford.

The schedules for the alternatives, like the basic cost estimates, appear to have been prepared competently. The project activities in the schedules are linked logically in a coherent path that seem to adequately reflect the alternative's project plan from start to finish. The estimated durations for the various activities seem reasonable, given the level of uncertainty associated with those activities at the current stage of project development.

Nonetheless, to some, the Phase I schedules appear conservative, and the schedules for Phase 2 seem too amorphous given the uncertainties to be resolved about Phase 2. This criticism has merit. If anything, the project team seems to be taking a rather risk averse approach, seeking to test first, before committing to an action. Given the uncertainty of the requisite technology, this seems appropriate. As uncertainty is resolved, the Phase 2 schedule will need to be updated.

The schedules are neither resource-constrained nor fully integrated with events external to the STP. For example, there is a potential for additional sludge to be generated from the clean out of K West Basin that hasn't been factored in the cost or schedule estimates. Similarly, there is a potential for a need to recover and treat additional fuel scrap from the basin floor after cleaning and removal of debris. Yet, for alternative analysis purposes, those shortcomings and omissions in scheduling would not likely have a significant effect on the inferences drawn about the preferred alternative. Clearly, those shortcomings and omissions should be addressed in subsequent planning steps. Yet, the additional cost of very detailed planning and scheduling during alternatives analysis will likely exceed the marginal benefit gained from that effort. However, a critical path, resource loaded schedule for near term activities and those activities for which a preferred alternative has been selected would provide a foundation for planning purposes and evaluating opportunities for overall project acceleration. Thus, a critical path, resource loaded schedule would be useful for Phase I and also for technology maturation required in advance of implementation of Phase II (e.g., retrievals from STSCs, treatment and packaging).

Project Management

The following are additional project management considerations that should be addressed as the STP project progresses.

Documentation of Project Decisions

Although the review of the alternatives evaluation indicates a clear desire to use the two phase approach to achieve more rapid removal of the K Basins sludge from the River Corridor, there appears to be insufficient formal documentation of (i) the Hanford 2015 vision (DOE 2009) that articulates completion of the STP as one of the important DOE priorities that impacts subsequent project planning and implementation, and (ii) recognition and concurrence by the regulatory authorities that taking the two phase approach will more rapidly achieve the near term objective of K Basins closure but may also result in a longer period before final sludge treatment and shipment to WIPP if programmatic priorities shift during interim storage at the Central Plateau. However, overall time to complete the project will be constrained by the availability of a suitable packaging facility to prepare treated sludge for shipment to WIPP.

Allocation of Risks

Although there is clear identification of project risks that may impact cost and schedule, there are inter-related activities that span both the STP and the K Basins closure project without clear allocation of responsibility and costs if those risks are realized. For example, how will costs be allocated if removal of debris from the basin results in delay and additional costs associated with completion of sludge retrievals? A second risk factor without clearly agreed upon allocation is general maintenance and hotel costs associated with T Plant should it be selected as the location of for interim sludge storage or other operations. Currently, the planning and decision process assumes, without documented agreement, that the STP will be responsible only for the incremental costs of facility modifications and operations necessary for the Project and no other T Plant operating costs. It is assumed that the work breakdown structure (WBS) dictionary and planning baseline will establish these relationships when submitted and approved.

Conclusions and Recommendations

This ETR evaluated the areas of project management, technical risks, regulatory risks, system risks and safety risks, emphasizing a systems approach for the STP to achieve its mission objectives. The following are the recommendations and the associated discussion with conclusions that provide the supporting rationale resulting from this review.

<u>In-basin Treatment versus Out-of-basin Treatment</u>

RECOMMENDATION 1. DOE should explicitly state the priority objectives to guide the STP decision processes. If removal of sludge from the River Corridor prior to 2015 is the clear programmatic priority, then the phased approach of removal of sludges from the K Basin to interim storage at the Central Plateau, followed by treatment, packaging, and shipment is necessary to meet this objective.

Discussion. Achievement of the 2015 Vision (DOE 2009) and the programmatic preference expressed by both the U. S. Department of Energy Richland Operations Office (DOE-RL) and EPA to remove the sludge from the River Corridor by approximately 2015 were the primary determinants for selecting the two phased approach whereby sludge would be removed from K

West Basin, transported to an interim facility at the Central Plateau where it would be stored, treated, and packaged for shipment to WIPP. The EPA considers the continuing presence of the sludge at the basin, delays in closure of the K Basins, and impediments posed by the basin to remediation of subsurface chromium contamination in the K Area as significant environmental risks and high priorities for Hanford remediation. The two phase approach was the only general project approach with a realistic opportunity to achieve the Hanford 2015 vision for the River Corridor and this, coupled with the stated EPA preference for the 2015 time period, were the primary factors that influenced the expert elicitation and alternatives evaluation process.

RECOMMENDATION 2. Both the technical and programmatic bases for selecting out-of-basin treatment should be clearly documented including attributes that favor and disfavor in-basin versus out-of-basin sludge treatment and packaging; the impact of these assumptions on cost and schedule estimates should be explicitly addressed.

Discussion. There are several technical factors that favor out-of-basin treatment and packaging of sludge retrieved from K West Basin, including reduced worker radiation dose, worker productivity concerns, present knowledge of sludge inventory and characteristics, and the complexity associated with designing and implementing an underwater process in the basin; these factors were significant considerations in the deliberations of project personnel, but are incompletely captured in the alternative selection basis. However, several factors also disfavor out-of-basin treatment, including: the possibility of delays in completing treatment and shipment of sludge after removal from the basins and Columbia River Corridor clean-up is achieved, i.e., absence of regulatory/schedule pressure; the potential need for additional sludge transfers to achieve treatment and packaging; and the potential for adverse changes in sludge characteristics during interim storage, making subsequent transfers, and treatment more difficult. Facilities (existing or new) will have be identified and either modified or constructed for interim storage and material packaging regardless of whether treatment occurs at K Basin or at the Central Plateau.

Primary Technical Project Components and Technical Risks

RECOMMENDATION 3.

a. Design of the interim storage configuration should be closely coupled to the selection and maturation of Phase II processing. An alternatives analysis and alternative selection process for Phase II treatment and packaging should be performed as soon as possible to facilitate integration of Phase I retrieval, Sludge Transport and Storage Container (STSC) design and storage strategy with Phase II treatment and packaging approaches. Alternatives analysis should include consideration of in-situ treatment (e.g., heated storage) followed by in-situ solidification and disposal in the interim storage container. The Technology Readiness Assessment (TRA)/ Technology Maturation Plan process should be used to inform the process development for Phase II.

b. Sampling and analysis of settler tube sludge during Phase I should include provision for direct measurement of hydrogen generation rates and quantities at controlled elevated temperature, in an appropriate environment, to facilitate planning and design of the Phase II treatment process.[14] Sufficient samples of engineered container sludge should be obtained to permit direct measurement of hydrogen generation rates if prior data is insufficient to support selected treatment conditions. Characterization of KOP material should be sufficient to bound the metallic U for quantity, particle size distribution, and surface area to adequately plan for (i) the number of Multicanister Overpacks (MCOs) to be produced; (ii) validate acceptable levels of hydrated material; and (iii) the potential for enhanced chemical reactivity of the material.

c. High priority should be given to maintaining and utilizing the Maintenance and Storage Facility (MASF) facility for design, operator training and troubleshooting throughout Phases I and II of the project. The MASF facility, employing appropriate surrogates, should be used to demonstrate (i) all sludge retrieval operations from within the basins (e.g., from engineered containers, settler tubes, KOPs), (ii) retrieval of sludges from STSCs after sludge settling, and (iii) solids handling in any proposed processing flowsheet (in-situ or using a separate plant). Solids handling processes such as these have a history of handling problems within the DOE complex and in commercial industry. Scaling up such processes is often difficult particularly when the nature of the solids is variable such as with the K Basin sludges. Full scale testing using a variety of simulants will reduce this uncertainty and improve the likelihood of success.

Discussion. Currently, the project does not have a well defined processing path for treatment and packaging of sludges after removal from the K Basin and transfer to interim storage. The absence of such a well defined processing path prior to removal from the K Basin, including timely technical maturation, produces the potential for scenarios where the ability to retrieve the sludge from interim storage containers and process the material creates unforeseen challenges and overall project inefficiencies, including additional future sampling and characterization, technology development and extended schedules for final disposition of the material.

The following are the primary technical components of the project and technical risks, as the ETF team has come to understand them:

a. *Retrieval of sludges from engineered containers and settler tubes.* The technical risks of these operations are associated mechanical and hydraulic operations to achieve sludge retrieval. Full-scale component and integrated testing at the MASF, including direct involvement of basin operators and feedback leading to design improvements, is an appropriate risk mitigation strategy. Appropriate bounding simulants for physical properties are in the process of being defined. This is an important matter because typically there are the problems associated with sampling materials comprised of fines or coarse particulates or a combination of both. Current measurement techniques such as yield strength may not be a sufficient discriminator for a mixture of granular and fine solids and therefore additional sludge characterization and simulant testing may be needed to provide confidence in equipment demonstration using simulants.

b. *Design and implementation of a strategy for transfer and interim storage of sludges, with or without treatment.* Several programmatic and technical factors will strongly influence the direction and design of transfer and storage, including (i) whether facilities developed for

[14] Measurement only of U metal content is insufficient because knowledge of the amount of U metal content will allow estimation of the total amount of hydrogen to be generated but not the rate of hydrogen generation because the particle size distribution of the U metal particles is not known (the combined particle size distribution of U metal and non U metal particles is measured and therefore the reactive surface area of U metal is not known).

interim storage, treatment and/or packaging of K West Basin sludges will include planning and integration with other site-wide Remote Handled Transuranic Waste (RH-TRU) management needs, (ii) whether interim storage will occur within an existing nuclear facility (i.e., T Plant) or at a new nuclear facility (potentially, using a cask on pad strategy), and (iii) whether treatment (U metal oxidation) and/or packaging for WIPP can be integrated with the transfer and storage container and interim storage system design. Current planning indicates transfer of the retrieved sludges directly from the engineered containers within the basin to STSCs. STSCs then would be relocated to the selected storage location.

c. *Treatment to reduce hydrogen generation to levels acceptable for shipment to and disposal at WIPP.* Currently, this project component is considered part of Phase II. The primary hydrogen generation mechanisms are through radiolysis and spontaneous oxidation of U metal in reaction with water. Hydrogen generation by U metal oxidation has been studied and reasonably well quantified reaction rates and heats of reaction have been determined. The U metal oxidation rate is highly exothermic and strongly dependent on temperature and reactive surface area (i.e., particle size distribution of U metal). However, the amount of U metal in the sludges and the specific hydrogen generation rates (as a consequence of U metal content and U reactive surface area) are not well defined for the sludges, especially for settler tube sludges. A sampling and analysis program is underway to reduce this uncertainty.

Pre-conceptual process development has been initiated for U metal treatment with warm water oxidation (at ca. 80-90 C and ambient pressure) in an agitated reactor as the currently favored treatment approach. Other potential approaches exist that warrant consideration including oxidation during storage in STSCs using heated storage[15]. Important factors in the treatment process selection will be the time frame and location for treatment. An alternatives evaluation and selection process has not been performed to establish the preferred treatment approach. Process development and testing will be required to sufficiently mature the treatment process for implementation, including direct measurement of specific hydrogen generation rates at anticipated process conditions.

d. *Packaging of treated sludges after recovery from STSCs and treatment to allow shipment to WIPP.* Currently, this project component also is considered part of Phase II. The Waste Acceptance Requirements for shipment to WIPP include (i) less than 1% free liquids, (ii) hydrogen generation rate, and (iii) curie and fissile gram equivalent (FGE) loading. Uncertainty in the inventory (specific activity and U metal content) associated with the sludges, the packaging approach (e.g., use of an absorbant or grouting), and the waste loading within individual shipping packages are the primary technical contributors to uncertainty in the number of packages (currently assumed to be in 30-gal drums) to be shipped to WIPP. Additional programmatic uncertainties impacting the number of packages and shipments to WIPP are discussed separately below. The current sampling and analysis program for sludges in the engineered containers and planned sampling and analysis program for the settler sludge once retrieved into an engineered container will help to reduce this uncertainty.

e. *Retrieval of KOP material and segregation of spent fuel scrap and debris.* The KOP contents will first be sampled and characterized to determine if existing processing facilities within K West Basin are sufficient to process this stream. Retrieval of KOP material from

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[15] Integration of treatment and interim storage at T Plant has the potential to significantly accelerate overall project completion if appropriate design and safety criteria can be met.

current locations will be accomplished by vacuuming and/or mechanical means including the potential for tipping into a receiving container within the basin. The current plan is to hydraulically wash the KOP contents, using the existing Primary Cleaning Machine and integrated water treatment system (IWTS), to remove sludge particles less than 600 µm, and spent fuel scrap greater than ¼ inch to the extent practicable. The remaining coarse fraction of the KOP contents will be dispositioned in MCOs. The sludge (< 600 µm) will proceed to the settler tubes to be sampled, characterized, retrieved and dispositioned with the settler tube sludge. From the washing process the course material will consist of two different streams: (i) material larger than 600 µm and smaller than ¼ inch; and (ii) material larger than ¼ inch (in one dimension). Required devices to separate the course material are being designed and tested at MASF. For the course material larger than 600 µm and smaller than ¼ inch, the KOP project plans to separate the metallic U material from the non-U material to minimize the amount of material that will need to be processed as spent nuclear fuel (SNF). The course material fraction larger than ¼ inch (in one dimension) will be visually sorted on a scrap sorter table to separate metallic U fuel scrap from the non-U material. The uncertainties associated with this project component are the inventory of material to be recovered and the effectiveness of the planned mechanical separations. The KOP material characterization, along with device design and testing with K Basin operator participation, are appropriate risk reduction strategies (Sullivan 2008).

f. *Disposition pathways for the Separated KOP material.* The KOP metallic U material is planned to be processed and managed as SNF, loaded into MCOs, transferred to the cold vacuum drying facility (CVDF) and dried, and then the MCOs will be transferred to the Canister Storage Building for interim storage until they can be shipped to a federal repository. The non-U material is planned to be managed with other basin debris as either Low-Level Waste and disposed in the Environmental Restoration Disposal Facility at Hanford or as transuranic waste (TRU), depending on final waste classification. Areas of technical uncertainty with the KOP project component include: (i) the number of spent fuel scrap canisters to be produced; (ii) how dry is dry enough for the SNF scrap; and (iii) the potential for enhanced chemical reactivity of the SNF scrap. Risk reduction strategies are being pursued (see 3.e., above) to help determine the number of MCOs to be produced, which is driven by the uncertainty in inventory estimates of the KOP material and the effectiveness of planned physical separation processes. The smaller particle size range of the KOP material and hydrated compounds more readily retain water and make drying more difficult. The smaller particle size range, and thus the increased surface area to volume ratio, will increase the potential for enhanced chemical reactivity, the pyrophoricity and combustibility characteristics of the KOP material destined for drying, packaging, and interim storage will need to be determined if sufficient information is not available after the KOP material has been characterized.

g. *Inspection and recovery of additional material after debris removal from the basin.* A separate project, the K Basin Disposition Project, is responsible for cleaning and consolidation or removal of debris, residual sludges and fuel scrap from the basin floor. This project will result in deposition of additional sludge onto the basin floor that requires transfer to engineered containers for retrieval, treatment, packaging and disposal. Final inspection of the basin floor may indicate the presence of spent fuel scrap requiring retrieval, washing and disposal analogous to the KOP material. However, the amount of material to be recovered as part of the final basin cleaning has been estimated and included in the project plan.

Phase I and Phase II Project Integration and Selection of an Out-of-Basin Interim Storage and Treatment Locations

RECOMMENDATION 4.

a. An alternatives analysis of sludge treatment and packaging process and facility options should be performed in order to evaluate potential technical, cost and schedule benefits for integration of development of preferred options with the design of sludge storage.

b. A high level review of the relationships between the project timing, processing needs, and facility requirements for the K Basins STP and other Hanford RH-TRU processing needs should be performed to determine if potential benefits can be gained through coordination between projects.

c. More detailed information should be developed and program planning completed to allow for a more thorough alternative facility analysis and selection process, recognizing that the construction of a new facility for treatment, packaging, and shipment of RH-TRU is a programmatic decision that should consider the needs of both the K Basins STP and other Hanford site-wide RH-TRU mission needs.

Discussion. The following provides a summary of the primary basis for selection of interim storage of sludge at the Hanford Central Plateau and the needs for closer integration of STP Phase I and Phase II along with more comprehensive evaluation of the Hanford site facility needs for RH-TRU treatment, packaging and shipment.

a. The initial alternatives analysis (CHPRC 2009a) was performed to compare potential cost, schedule, and technical advantages and disadvantages of process sequences for managing engineered container sludge and settler tube sludge in the K Basin with the primary distinguishing feature amongst options being the (i) the extent of operations within the K Basin versus at a Central Plateau facility (either at T-plant or a new facility), and (ii) the specific sequence of process steps including sludge retrieval, storage, treatment and packaging for disposition at WIPP. As a result, initial cost estimates included notional assumptions about aspects of processing that were common amongst options and did not provide significant detail in process or facility configurations. Results of this initial alternatives analysis indicated a relatively small distinction in life cycle costs for in-basin processing compared to transfer of the sludges to a Hanford Central Plateau facility followed by storage, treatment and packaging at the Central Plateau. However, early transfer of sludges to the Central Plateau facilitates closure of the K Basins consistent with the Hanford 2015 Vision (DOE 2009) for the River Corridor and regulatory preferences (as discussed above). Technical factors did not strongly distinguish between the options at that level of evaluation detail. The initial alternatives analysis then was followed with a more detailed evaluation of options for sludge storage at the Central Plateau, comparing (i) modification and use of the T Plant facility for storage with (ii) design and construction of a new cask on pad storage facility (CH2M HILL Plateau Remediation Company (CHPRC) 2009b). This comparison indicated cost neutrality and a schedule benefit to use of the T Plant facility, rather than construction of a new facility, but only examined costs associated with facility development and operations for sludge storage in STSCs. Still needed is a detailed analysis of integration of storage, treatment and packaging steps, which currently is to be considered in the Phase II alternatives analysis. Potentially, there are life-cycle cost and schedule benefits to integration of design and implementation of Phase I activities with Phase II activities at the Central Plateau, but an integrated alternatives analysis with sufficient detail to distinguish amongst treatment and packaging process and facility options has not been completed.

b. The ETR team has been briefed that the K Basins sludge material accounts for less than 1% by volume, 11% by total Curies (Ci) and 15% by 72-B shipments of the RH-TRU to be generated on the Hanford site. The potential for the facility selected to meet multiple RH-TRU missions has not been evaluated at the site-wide, programmatic level. Insufficient evaluation has been completed to date to select from amongst these options. The relationships between the project timing, processing needs, and facility requirements for the K Basins STP and other Hanford RH-TRU processing needs have not been considered and thus the potential for synergies and cost or schedule benefits that might be gained through project coordination are unknown.

<u>Programmatic Uncertainties that Affect Shipments to WIPP</u>

RECOMMENDATION 5.

a. DOE-RL and WIPP should concur with the assumptions that serve as the planning basis for shipments to WIPP, thus allowing for appropriate project design basis assumptions. The resulting assumptions, requirements and agreements should be formalized through an interface control document.

b. Unresolved issues with respect to waste classification and waste loading assessments should be definitively resolved as rapidly as possible.

Discussion. The number of packages (e.g., 30-gal drums) and shipments to WIPP may be impacted by the resolution of several programmatic issues:

a. The project currently assumes that approximately 50% of the WIPP RH-TRU capacity to ship and receive waste is available to Hanford for shipping of packaged sludge to WIPP, allowing for 125 shipments per year (assuming WIPP capacity to receive RH-TRU at 250 per year or 1 per day). However, packaged sludge from K Basins currently is estimated to be less than 15 percent of the total RH-TRU shipments needed from Hanford to WIPP (see footnote bottom of page 17). The actual number of 72B shipping casks available will be a function of U. S. Department of Energy Office of Environmental Management (DOE-EM) priorities for shipments to WIPP including consideration of competition within Hanford and between sites for shipping of other RH-TRU waste form packages to WIPP. A further consideration will be the availability of RH-TRU disposal panels within WIPP given the anticipated shipping interval and WIPP operations.

b. The classification of sludge removed from the settler tubes has not been fully resolved and agreed to by WIPP. The project currently assumes that the sludge removed from the settler tubes will be classified as RH-TRU but the potential remains for the settler tube sludge to be classified as SNF. Until agreement on sludge classification is reached and regulatory approval is obtained for blending, the project cannot blend sludge retrieved from settler tubes with sludge retrieved from engineered containers because of concern about comingling regulatory waste classifications. Preliminary analysis indicates that blending of settler tube sludge with engineered container sludge will facilitate greater waste loading of RH-TRU waste form packages because settler tube sludge loadings will be limited by FGE while engineered container sludge loading will be limited by waste volume. Initial estimates suggest that this may have the potential to reduce the required number of shipments to WIPP by up to 30%. However, regulatory uncertainty regarding waste classification and acceptability of blending indicates that, at this time, project planning should not (and DOE-RL currently does not) include credit for reducing the number of RH-TRU packages through sludge blending.

c. Dose-to-curie (DTC) analysis requires sufficient knowledge of specific radionuclides present in the final waste form in order to use the dose measurement to calculate the total curies in each waste package from the combined contribution of the radionuclides. The STP has used prior DTC calculations by other sites that indicate a large uncertainty can be anticipated (over 100%) but may be mitigated as additional information is gained regarding the radioisotopic ratios and the final waste form. The DTC analysis will be essential in Phase II operations where the final waste form for WIPP disposal is generated to confirm compliance with applicable WIPP transportation and disposal requirements.

Schedule and Cost Evaluation

RECOMMENDATION 6.

a. A life-cycle cost analysis should be performed consistent with guidelines for performing cost effectiveness analysis provided in OMB Circular A-94 (OMB 1992).

b. A critical path, resource loaded schedule should be developed for Phase I and technology maturation required in advance of implementation of Phase II (e.g., technology maturation needed for retrievals from STSCs, treatment and packaging, as well as in support of Phase I) to provide a foundation for planning purposes and evaluating opportunities for overall project acceleration.

Discussion. The estimates for the basic costs and schedules are reasonable. However, the life cycle cost analysis, as presented by the project team, is incomplete. The analysis identified the expected overall expenditures for each alternative, but did not express those expected future costs in present worth terms before inferring any differences in costs. (The present worth is the standard criterion for evaluating life cycle costs, as prescribed by the Office of Management and Budget and in DOE regulations and cost guides [OMB 1992, AACE 2005].)

The ETR team, using the basic cost estimates and factoring in the uncertainties associated with those estimates, performed its own probabilistic analysis of the life cycle costs of the four leading alternatives: Alternatives 6-T, 6-N, 7-T, and 7-N (see Table 2, below, for definitions)[16]. The ETR analysis suggests that, statistically, there are no meaningful cost differences among those alternatives. A summary chart of those findings are presented below in a box-and-whisker

[16] The cost evaluation looked only at the EC/ST alternatives analysis and did not address the ongoing KOP disposition activities.

plot format. The box portion of each diagram reflects the expected present worth costs between the 25th and 75th percentiles of the likely distribution of costs. The ends of the whiskers reflect the lower bound and upper bound costs of that distribution. The allocation of costs that comprise the overall cost estimates indicate that only less than 20 percent of the project's total cost is associated with the retrieval of wastes from the K Basin and subsequent interim storage (Phase I). The selection of the sludge treatment process and facilities for treatment, packaging and loading for shipment to WIPP, which have not yet been determined, represent more than 80 percent of the total project costs (Phase II).

The schedules for each alternative are divided into two phases. Phase I comprises those activities that occur at the River Corridor. Phase II comprises those activities that will occur on the Central Plateau. This division in each alternative's overall project schedule seems to be a sensible approach for showing the project team's emphasis on removing the sludge from the River Corridor as quickly as possible. The overall determinant for completion of the STP mission (and initiation of RH-TRU shipments to WIPP) is the availability of a facility for treatment, packaging and shipment of RH-TRU, which currently is not available at Hanford.

The schedules for the alternatives, like the basic cost estimates, appear to have been prepared competently. The project activities in the schedules are linked logically in a coherent path that seems to adequately reflect the alternative's project plan from start to finish. The estimated durations for the various activities seem reasonable, given the level of uncertainty associated with those activities at the current stage of project development.

Nevertheless, the schedules are neither resource-constrained nor fully integrated with events external to the STP. For example, there is a potential for additional sludge to be generated from the clean out of K Basin that has not been factored in the cost or schedule estimates but are included as part of the project risk management plan. Similarly, there is a potential for a need to recover and treat additional fuel scrap from the basin floor after cleaning and removal of debris. Yet, for alternative analysis purposes, those shortcomings and omissions in scheduling would not likely have a significant effect on the inferences drawn about the preferred alternative. However, a critical path, resource loaded schedule for near term activities and those activities for which a preferred alternative has been selected would provide a foundation for planning purposes and evaluating opportunities for overall project acceleration. Thus, a critical path, resource loaded schedule would be useful for Phase I and also for technology maturation required in advance of implementation of Phase II (e.g., retrievals from STSCs, treatment and packaging).

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Appendix A – ETR Team Member Biographies

Dr. David S. Kosson. Dr. Kosson is Professor and Chair of the Department of Civil and Environmental Engineering at Vanderbilt University, where he also has joint appointments as Professor of Chemical Engineering and Professor of Earth and Environmental Sciences. He also is co-principal investigator (with Charles Powers) of the multi-university Consortium for Risk Evaluation with Stakeholder Evaluation. Professor Kosson's research focuses on management of nuclear and chemical wastes, including process development and contaminant mass transfer applied to groundwater, soil, sediment and waste systems. His research on leaching of contaminants from wastes and construction materials is currently providing the foundation for environmental regulation of these materials at USEPA, the Netherlands Ministry of Environment and the European Union's Directorate General for the Environment. Professor Kosson also has provided expertise and leadership for the National Academies, and as advisory to the Department of Defense, for more than a decade on demilitarization of chemical weapons in the United States and abroad. Professor Kosson has authored more than 100 peer-reviewed professional journal articles, book, book chapters and other archival publications. He received his Ph.D. in Chemical and Biochemical Engineering from Rutgers University, where he subsequently was Professor of Chemical and Biochemical Engineering.

Dr. Steven L. Krahn. Dr. Krahn is the Director of the Office of Waste Processing Engineering & Technology, within the Office of Environmental Management, U.S. Department of Energy (DOE-EM); this office targets engineering and technology investments to identify, advance, develop, and implement engineering concepts, technologies, and practices that improve the performance of DOE cleanup projects and provides interdisciplinary engineering consultation, guidance, expertise, and continuity to DOE-EM. Prior to rejoining the government in 2007, Dr. Krahn spent 30 years in technical and project management positions of increasing responsibility in government, private industry and the military, including: the management of the $140 million complex overhaul of a nuclear submarine; technical direction of the research and development program for a major DOE reactor program; providing technical direction and leadership for a federal agency providing safety oversight to the U. S. nuclear weapons complex; directing a $25 million division in an engineering services company; and providing technical consulting services to the U. S. nuclear industry. He holds a BS in Metallurgical Engineering from the University of Wisconsin, a MS in Materials Science from the University of Virginia, a Doctorate in Public Administration from the University of Southern California, and is a graduate of the Bettis Reactor Engineering School (USDOE).

Dr. David R. Gallay. Dr. Gallay has more than 30 years of experience as an engineering manager and research analyst. Currently, as the program director of LMI's Infrastructure and Engineering Management practice, he provides research and analysis services to public-sector clients in areas involving public works-related program and project management, engineering economics and finance, and cost uncertainty analysis. Among his projects for the Department of Energy, Dr. Gallay has managed the economic and financial analyses of four business case studies that examined the alternatives to restructure the National Nuclear Security Administration's complex of nuclear laboratories and nuclear material storage locations throughout the United States. He has led independent assessments of business case analyses advocating the acquisition and operations of office buildings, multi-purpose laboratory facilities, and other infrastructure through private sector financing, instead of conventional line-item federal budgeting, at or near five Department of Energy installations. He has also been asked repeatedly by senior management at the Department of Energy to serve on teams of outside experts to review, from both an economic and technical perspective, the Department's plans for investments in capital infrastructure to carry out high-cost initiatives, such as the disposal of the national stocks of surplus plutonium and uranium. In addition to his affiliation with LMI, Dr. Gallay is an adjunct faculty member at The George Washington University, where he teaches courses in finance and engineering economics. Before joining LMI, he was a career Army officer who served in military engineer and operations research positions. He holds a bachelor of science in engineering from the U.S. Military Academy, a master of science in civil engineering from Purdue University, a master of science in systems management from the University of Southern California, and a doctorate in engineering management from The George Washington University. He is a registered professional engineer and a certified cost engineer.

Dr. Gary L. Smith. Dr. Smith is a staff scientist with the Pacific Northwest National Laboratory (PNNL) and is currently on assignment to the Office of Waste Processing, Engineering & Technology within the Office of Environmental Management, U.S. Department of Energy. Dr. Smith has been involved with all aspects of the nuclear waste flowsheet for a number of years, taking on roles of increasing responsibility in both a technical capacity and in management. He has extensive project management experience, most recently serving as PNNL's Deputy Program Manager for the River Protection Project – Waste Treatment Plant Project Support Program. This program contributes significantly to the characterization, retrieval, pretreatment, and vitrification of Hanford tank waste for the Waste Treatment and Immobilization Plant (WTP) project. Prior to this role, Dr. Smith served as a technical advisor, directly supporting the WTP contractor. He has managed and acted as principal investigator on projects ranging from vitrification and glass product testing to examining the processability of slurry feeds as a function of batch chemistry for laboratory-, bench- and pilot-scales. Dr. Smith has published more than 70 refereed journal articles, technical reports, and conference papers as well as numerous classified documents. He has co-edited three volumes of *Ceramic Transactions,* dealing with "Environmental and Waste Management Issues in the Ceramic Industry." He is a fellow of the American Ceramic Society (ACerS) and ASTM International. Dr. Smith is chair of ASTM International Committee C-26 on the Nuclear Fuel Cycle and chair of Subcommittee C26.13 on Spent Fuel and High Level Waste, committees that develop consensus standards for the international nuclear community. He also is vice chair of the U.S. Nuclear Technical Advisory Group and past chair of the ACerS Nuclear and Environmental Technology Division. He holds a Ph.D. in Materials Science & Engineering from the University of Arizona.

Mr. Jim J. Davis. Mr. Davis has over 21 years of nuclear experience including 17 years with the Department of Energy (DOE), predominately in the field of radioactive waste management at the Hanford, WA site. Currently he works for DOE-EM, Office of Standards and Quality Assurance (EM-64) in the area of quality assurance related to environmental management projects. Prior to that he worked for DOE as a project manager on tank farm (TF) waste retrieval projects and programs for over 12 years which included oversight of technology development, engineering design, procurement, construction and operations. He qualified as a Safety System Oversight (SSO) for transfer systems in the TF project and on mechanical systems for the Waste Treatment and Immobilization Plant (WTP), at which he supported engineering design and construction for 4 years. Prior to coming to the department, Jim worked 4 years in Naval nuclear refueling operations at Puget Sound Naval Shipyard. He received a Bachelor of Science in Engineering degree from the University of Washington in 1985.

Mr. David M. French. Mr. French holds bachelor degrees in Chemistry (analytical/instrumental), Biology (high altitude ecology), MBA (information management systems) and a J.D. from Northwestern in environmental and natural resource law. Mr. French is a member of the Colorado State Bar and holds an active Q clearance. Mr. French currently is a consultant at Los Alamos National Laboratory (Carlsbad Office) to DOE-Carlsbad Field Office. Mr. French's experience with DOE facilities and operations began in 1979 at Hanford and has continued since that time with work at Los Alamos, Rocky Flats, Idaho, WIPP, SRS and ORNL. Currently, Mr. French is providing technical and regulatory support to the DOE-Carlsbad Field Office through the Los Alamos National Laboratory Carlsbad Office. This work includes working with the various TRU waste sites and their facilities to more efficiently treat, package and transport their TRU waste to WIPP. Mr. French provides specific assistance to a number of TRU waste treatment processes in order to help the management and engineering staffs develop treatment processes that will effectively and efficiently generate certifiable WIPP waste. Prior DOE complex work includes program and project management in waste processing, analytical chemistry laboratories, packaging and shipment of radioactive wastes. Also, Mr. French was Of-Counsel attorney to the Washington, D.C. law firm of Patton Boggs in the areas of Public Policy, environmental law and government contracting. His work at Patton Boggs also entailed development of federal/state regulatory compliance programs for several fortune 100 firms having world wide operations with multi-national jurisdictional issues. Mr. French's other work includes safeguards and security assessments and evaluations for radioactive material transports along with vulnerability assessments on specific material packages from terror activities. Mr. French has also vulnerability assessment on various world-wide high-value nuclear facilities. Other assessments include evaluations low-yield nuclear detonations and dirty bombs on key U.S. cities. Mr. French also served as a technical and regulatory consultant to the University of New Mexico Law School in its work with the DOE on the Water for Energy project. Mr. French has authored or coauthored a number of articles, presentations and briefing papers on subjects ranging from safeguards and security, transportation vulnerabilities, terror attacks using low yield nuclear devices to innovative technologies to detect ^{238}Pu in various waste forms.

Dr. Arthur W. Etchells III. Dr. Etchells is a world recognized authority in the field of mixing for the process industries. He is a chemical engineer with BS and MS from University of Pennsylvania and doctorate from University of Delaware. For thirty nine years he worked for the DuPont Company and for thirty years as an internal consultant for the many diverse DuPont businesses in the field of fluid flow with emphasis on mixing and slurry transport. He has achieved the highest technical level of DuPont Fellow and the highest technical award, the Lavoisier Medal. His outside activities such as teaching in universities and continuing education courses, publications, and lect ures and his leadership in the world technical community have made him widely known and highly respected. He has contributed two chapters to the recent Handbook of Industrial Mixing (Wiley 2003) and is now working as an editor for a new supplemental edition. He is a past president of the North American Mixing Forum and winner of their award for contribution to mixing technology. He retired from DuPont in November 2002 and now works as an independent contract consultant. He is currently working for DuPont Safety

Resources Business helping the Bechtel Company develop a facility for immobilizing radioactive waste at the Hanford site in the state of Washington along with other consulting for a number of companies outside of Dupont.

Appendix B - ETR Charter

U.S. Department of Energy
Office of Environmental Management
Engineering and Technology

External Technical Review (ETR)
CHARTER

Major Risk Factors
Sludge Treatment Project (STP)
Richland, WA

March 2009

Sludge Treatment Project External Technical Review

Introduction / Background

Originator

This External Technical Review was requested by Inés Triay, Acting Assistant Secretary for Environmental Management (EM-1). This project was presented to EM – 1 in a telephone conference on 12 January 2009. After briefly reviewing this project, EM-1 requested an External Technical Review as a means to address several issues. The issues are:

- Is a new facility needed? Within this question is the issue of extent as there is within EM an aversion to so-called "monuments to waste processing." The real issue is can we achieve the desired results with a minimum of new construction or is new construction like the Waste Treatment Plant proposed?
- Why does it take ten years to start shipping treated sludge to WIPP? Why is the time scale the same whether the work takes place at-basin or at the Central plateau?
- Do the advantages of moving the sludge and treating and packaging it on the Central Plateau outweigh the advantages of doing all the work at K Basin?

Responsible Organization

The Office of Engineering and Technology (EM-20) is responsible for conducting and completing this External Technical Review. The Office Director, Office of Waste Processing (EM-21), will be the team Lead.

Summary Description of Sludge Treatment Project

Sludge Characteristics

K Basin sludge has been characterized through sample collection and analysis.[17] Sludge sampling campaigns have been conducted using the US EPA Data Quality Objectives/Sampling and Analysis Plan methodology[18]. A total of about 32 liters of wet sludge has been collected in 68 samples. Sludge characterization is based on samples taken in the K East Basin prior to Spent Nuclear Fuel processing and sludge recovery/consolidation activities. The sludge critical characteristics used in the alternatives analysis are summarized in Table 1. Additional sampling is planned to support nuclear material accountability and to provide confirmatory analysis for process development and design.

[17] Sludge characterization results are summarized in HNF-SD-SNF-TI-015, revision 13A, Volume 2, *Spent Nuclear Fuel Project Technical Databook Vol. 2, Sludge*, Fluor, Richland Washington

[18] An example of the data quality objectives methodology applied to the K Basin sludge sampling and analyses is provided in WHC-SD-SNF-DQO-008, revision 0B, April 2000, *Data Quality Objectives for K East Basin Canister Sludge Sampling*, Fluor Hanford, Richland Washington

Table 1. Sludge Critical Characteristics

Characteristic	Container	Settler
Volume (m^3)	23.5	5.4
Wet Density (g/cm^3)	1.47	3.0
Volume Fraction Water	0.75	0.65
Settled Sludge (Metric Tons)	34.5	16.2
Uranium (Metric Tons)	3.415	10.260
Uranium Total (g/cm^3)	0.15	1.9
Wt% U total-per cm^3	9.9	63.3
U metal (g/cm^3)	0.0114	0.063
U metal Total (kgs)	267.9	340.2
Wt% U metal-per cm^3	0.78	2.1
TRU (nCi/cm^3)	5.56E+04	6.11E+05
TRU (nCi/g)	3.79E+04	2.04E+05
FGE/m^3	1.20E+03	1.38E+04
Decay power (W/m^3)	6.38E+00	8.72E+01
OIER Volume (m^3)	1.4	NA
OIER (kgs)	1.67E+03	NA

FGE – Fissile Grams Equivalent
OIER – Organic Ion Exchange Resin
NA – not applicable

The composition of the sludge in the engineered containers is primarily iron and aluminum oxides, concrete grit, sand, dirt, paint chips, and operational and biological debris. It is contaminated with fuel corrosion products and small fragments of metallic uranium. The sludge in the Settler Tanks ranges in particle size from a few microns to <600 microns. It is expected to be primarily uranium corrosion products and fission and activation products, with some remaining metallic uranium. This projected inventory of sludge in the Settler Tanks is based on previous characterization of sludge samples from fuel canisters and observations of ongoing hydrogen gas generation from the stored sludge. Settler Sludge may also contain lesser quantities of iron and aluminum oxides, sand, Grafoil® (graphite gasket material) fragments, concrete grit, dirt, and other operational debris.

Sludge Processing Functions

In processing the K Basin sludge into a final waste form suitable for disposal at the WIPP, additional requirements will be applied, including DOE-RL direction and guidance. However, at this stage of the alternatives analysis, only those requirements that derive specific sludge processing functions were used for evaluating alternatives. Additional functions were identified for sludge mobilization, interim storage, transfer, onsite transportation, off-site transportation, and WIPP Certification and Transport. The complete set of sludge processing functions includes:

- **Sludge Mobilization:** Process that mobilizes and removes the sludge from the storage containers
- **Pretreatment:** Process that separates uranium metal from a sludge stream
- **Treatment:** Process that reacts uranium metal for hydrogen mitigation, regardless of whether pretreatment function is applied
- **Interim Storage:** Storage of the sludge on the Hanford Site as a slurry prior to packaging
- **Sludge Transfer:** Process that moves sludge between other identified functions
- **Packaging:** Process that incorporates sludge into a waste form suitable for disposal at WIPP
- **On-site Transportation:** Transportation of the sludge slurry or a solid in a container within the confines of the Hanford Site using existing approved casks
- **Off-site Transportation:** Transportation of the sludge in appropriate form from the Hanford Site to an off-site facility for pretreatment, treatment, and/or packaging using existing approved casks
- **WIPP Certification and Transport:** Certification that the final waste form package meets WIPP transport and disposal requirements, and transport of the waste package to WIPP

Functions are grouped together to form integrated alternatives for sludge processing. Not all of these functions need be performed by a single alternative. For example, if sludge pretreatment is not performed, then the treatment function processes all of the sludge instead of the uranium metal fraction. Additionally, some or all of these functions can be performed at the K West Basin, at the 200 Area Central Plateau, or at facilities located away from the Hanford Site (i.e., off-site).

This Alternatives Analysis took advantage of the large number of past studies on sludge disposition as a starting point to identify viable technologies, facilities, and transportation methods for accomplishing the required sludge processing functions. These past studies were also one source of the data used in this evaluation. Additionally, new technologies were identified to accomplish these functions. At the initial stage of generating and evaluating alternatives, methods were not identified for the sludge mobilization, sludge transfer, and WIPP Certification and Transport functions because these functions are common to all alternatives and do not discriminate among alternatives. These functions were included in the alternatives evaluation performed by the CHPRC DSB discussed later.

These technologies, facilities, and transportation methods were then combined into numerous unique alternatives that accomplish the required sludge processing functions. Technologies discussed are representative of technologies that could perform required functions.

An STP engineering evaluation concluded that each function would be evaluated in the Alternative Analysis process using the corresponding methods listed in Table 2.

Table 2. Methods used for Functions in Alternatives Analysis	
Functions	**Methods**
Pretreatment	Elutriation is representative of the pretreatment function used for alternatives analysis based on prior testing of this technology using sludge simulants.[19]
Treatment	Ambient pressure warm-water oxidation or in-drum heating of the packaged sludge to oxidize the uranium metal is representative of the treatment functions used for alternatives analysis. These methods were selected based on prior testing of this technology using actual sludge samples and international data on reaction of uranium metal with water.[20]
Interim Storage	After examining existing available facilities for interim storage of K Basin sludge, T Plant or a new interim storage facility were identified as the only viable facilities.
Packaging	An absorbent, grout, or combination is suitable for mixing with the sludge slurry to meet WIPP requirements for the final waste form in the 30-gallon drum package.
On-site Transportation	For on-site transportation of packaged sludge, the drum will be placed into a shielded on-site interim storage container (ISC). The only existing approved casks for onsite transportation of large (i.e., approximately 2 m^3) of sludge as a slurry is the Sludge Transport System (STS) cask.
Off-site Transportation	Off-site Transportation of large quantities of sludge as a slurry for off-site processing is not viable due to the lack of approved shipping containers and casks. Therefore, off-site transportation and processing methods were eliminated.

As a result of the alternatives evaluation process conducted by the STP engineering team, the seven unique alternatives listed in Table 3 were identified for processing the K Basin sludge into a final waste form suitable for disposal at the WIPP.

[19] HNF-3132, 1998, *K Basin Sludge/Resin Bead Separation Test Report, Rev. 0*, D. Squier, Fluor Hanford, Richland Washington

[20] PNNL-17815, 2008, *Uranium Metal Reaction Behavior in Water, Sludge, and Grout Matrices*, C. H. Delegard and A. J. Schmidt, Pacific Northwest National Laboratory, Richland Washington

Table 3. Description of Seven Alternatives Initially Identified for Sludge Processing	
Alternative	**Description of Functions**
1	• Retrieve sludge from Engineered Containers • Conduct sludge Pretreatment and Treatment in the K West Basin • Transfer the treated sludge as a slurry in the STS cask to the 200 Area Central Plateau • Interim-store the treated sludge in either T Plant or a new facility on the 200 Area Central Plateau • Package the treated sludge into a final waste form (grout or absorbent) suitable for disposal at WIPP in a new packaging facility located on the 200 Area Central Plateau • Interim store the packaged sludge until containers are packaged for shipment to WIPP
2	• Retrieve sludge from Engineered Containers • Conduct sludge Pretreatment and Treatment in the K West Basin • Package the treated sludge into a final waste form (grout or absorbent) suitable for disposal at WIPP in a new packaging facility located at the K Basin • Transport the packaged sludge in ISCs to the 200 Area Central Plateau for interim storage in a new facility • Interim-store the packaged sludge until containers are packaged for shipment to WIPP
3	• Retrieve sludge from Engineered Containers • Package the untreated sludge into a final waste form (absorbent) suitable for disposal at WIPP in a new packaging facility located at the K Basin • Transport the untreated packaged sludge in ISCs to the 200 Area Central Plateau for interim storage in a new facility • Interim-store the untreated packaged sludge until containers are packaged for shipment to WIPP
4	• Retrieve sludge from Engineered Containers • Package the untreated sludge into a final waste form (grout) suitable for disposal at WIPP using new equipment located underwater at the K Basin • Transport the packaged sludge in the ISCs to the 200 Area Central Plateau for interim storage in a new facility • Treat the packaged sludge to oxidize uranium metal by heated storage of the waste containers • Interim-store the treated packaged sludge until containers are packaged for shipment to WIPP
5	• Retrieve sludge from Engineered Containers • Package the untreated sludge into a final waste form (grout) suitable for disposal at WIPP using new equipment located above water at the K Basin • Transport the packaged sludge in ISCs to the 200 Area Central Plateau for interim storage in a new facility • Treat the packaged sludge to oxidize uranium metal by heated storage of the waste containers • Interim-store the treated packaged sludge until containers are packaged for shipment to WIPP
6	• Retrieve sludge from Engineered Containers • Transfer the untreated sludge as a slurry in the STS cask to the 200 Area Central Plateau • Interim-store the untreated sludge in either T Plant or a new facility on the 200 Area Central Plateau • Conduct sludge Pretreatment and Treatment in a new facility located on the 200 Area Central Plateau • Package the treated sludge into a final waste form (grout or absorbent) suitable for disposal at WIPP in a new packaging facility located on the 200 Area Central Plateau • Interim-store the packaged sludge until containers are packaged for shipment to WIPP
7	• Retrieve sludge from Engineered Containers • Transfer the untreated sludge as a slurry in the STS cask to the 200 Area Central Plateau • Interim-store the untreated sludge in either T Plant or a new facility on the 200 Area Central Plateau • Package the untreated sludge into a final waste form (grout) suitable for disposal at WIPP in a new packaging facility located on the 200 Area Central Plateau • Treat the packaged sludge to oxidize uranium metal by heated storage of the waste containers • Interim-store the packaged sludge until containers are packaged for shipment to WIPP

Reducing the Number of Alternatives to Three

These seven alternatives, including the information generated to evaluate these alternatives (see Volume 2, section 5), underwent a rigorous review by an Independent Review Committee (IRC) in September 2008. The minutes of the IRC meetings to review the seven alternatives are included in Volume 2, Appendix Q. The IRC membership and curricula vitae are provided in Volume 2, Section 10. The IRC assessed the alternatives development process and the seven selected alternatives. Besides the IRC, the review included representatives from DOE, EPA, Defense Nuclear Facilities Safety Board and WIPP. The IRC concluded that the project had followed a sound process for developing these seven alternatives. The IRC then recommended a ROM life-cycle cost and schedule analysis and a preliminary Hazards Consideration consistent with expectations in DOE STD-1189-2008 for the seven selected alternatives, which the STP engineering team prepared.

The preliminary Hazards Consideration[21] review included representation from Nuclear and Process Safety, Criticality Safety, Industrial Safety and Hygiene, Radiological Control, Project Engineering, and Fire Protection disciplines and was consistent with the expectations of DOE-STD-1189-2008. This preliminary Hazards Consideration review determined the following:

1. None of the alternatives exhibit a clear, distinct safety advantage.
2. Only safety significant controls are needed (i.e., no safety class controls) for each alternative.
3. There is no unique or unanalyzed hazard associated with any of the seven alternatives.

The schedule analysis focused on the critical path of each alternative to remove sludge away from K Basins and the Columbia River, and is summarized in Figure 3-1. At this point, the seven alternatives were divided into two phases:

1. Movement of sludge from K Basins and interim storage is Phase 1 of the project.
2. Packaging, storage, and preparation for shipment to WIPP are in Phase 2.

Alternatives 1, 6, and 7 transfer sludge as slurry to the 200 Area Central Plateau prior to packaging. This analysis shows alternatives 1, 6, and 7 remove the sludge from K West Basin five to nine years faster than Alternatives 2 through 5, which package sludge at the K Basins. Alternatives 1, 6, and 7 satisfy the DOE objective to remove the sludge off the River Corridor as soon as possible in comparison to Alternatives 2 thru 5.

Results of the ROM cost analysis show life-cycle costs developed at this stage of the analysis are the same for each alternative within the accuracy of the estimate. However, Phase 1 costs, which are about 1/3 of the estimated ROM life-cycle costs, are significantly lower for Alternatives 1, 6, and 7, because fewer operations occur at K Basins with these alternatives.

[21] KBC-39341, revision 0, 2008, Sludge Treatment Project Pre-Conceptual Alternatives Hazards Consideration, CH2M HILL Plateau Remediation Company, Richland Washington

Alternatives 1, 6, and 7 were selected by the STP for further evaluation by the DSB based on the analysis discussed above. The decision to reduce the number of alternatives to be studied further from seven to three is supported by the following:

- Hazards consideration shows no clear advantage or disadvantage for any alternative.
- Phase 1 schedule advantage for Alternatives 1, 6, and 7 with respect to Alternatives 2, 3, 4, and 5.
- Phase 1 cost advantage for Alternatives 1, 6, and 7 with respect to Alternatives 2, 3, 4, and 5.
- No advantage or disadvantage in life-cycle cost for any alternative.
- IRC concurred in October 2008 with the down selection to three alternatives and DOE-RL agreed.

Three to One

Alternatives 1, 6, and 7 were developed in greater detail by the STP engineering team prior to the DSB rating and ranking of each alternative. Pre-conceptual designs were developed sufficiently to provide supporting information for an Association for the Advancement for Cost Engineering Class 4 cost estimate (-30%/+50% accuracy range on capital costs) and schedule. At this stage of alternatives development, it became necessary to compare interim slurry storage at a new facility with interim slurry storage in T Plant for each of the three alternatives. Therefore, sub-alternatives 1N, 1T, 6N, 6T, 7N, and 7T were created, with the "N" designating a new interim storage facility path and the "T" designating a T Plant path. The details of the cost and schedule analysis, with supporting design concepts, are provided in Volume 2, Section 7.

The following five selection criteria were identified in the Decision Plan for rating and ranking the three alternatives: Safety, Regulatory/ Stakeholder Acceptance, Technical Maturity, Operability and Maintainability, and
Programmatic Aspects.

Safety: Safety input to the final three alternatives was provided following the broader input to the preliminary hazards consideration described in Section 3.2. Each of the safety disciplines (i.e., Nuclear and Process Safety, Criticality Safety, Industrial Safety and Hygiene, and Fire Protection) evaluated the three pre-conceptual design as they exist at this time. In each case, the safety disciplines used a go/no-go criterion for the alternatives, as specified in the Decision Plan. It was determined that each alternative could be configured to adequately control the respective hazards by using well established mitigation methods, and as a result, no discriminators between alternatives were identified[22].

Regulatory/ Stakeholder Acceptance: Stakeholder input has been received as public comments from past K Basins remedial action planning in support of the CERCLA ROD[23] and ROD amendment.[24] The DNFSB has also provided input in the form of DNFSB Recommendations[25].

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[22] KBC-39341, revision 0, 2008, Sludge Treatment Project Pre-Conceptual Alternatives Hazards Consideration, CH2M HILL Plateau Remediation Company, Richland Washington

[23] EPA/ROD/R10-99/059, 1999, *Record of Decision for the K Basins Interim Remedial Action*, U.S. Environmental Protection Agency, Richland, Washington

[24] EPA, 2005, *ROD Amendment for the K Basins Interim Remedial Action,* U.S. Environmental Protection Agency, Richland, Washington

The development of regulatory documentation is achievable in all alternatives and is not a discriminator between alternatives. Since none of the alternatives treat sludge soon after removal from the Engineered Containers, and an "Explanation of Significant Differences" or an amendment to the CERCLA ROD will be needed. Development of these documents is achievable within the project schedule.

Technical Maturity: Likely technologies to perform functions were selected based on previous studies and eliminated due to perceived cost and /or complexity. These technologies are representative, but not definitive.

The DOE Environmental Management (DOE-EM) guidance on determining technology readiness[26] was applied informally at the pre-conceptual STP design stage to provide a preliminary high-level assessment of technical risk associated with the three alternatives. The expectation of this high-level TRL examination was that technology maturity differences might provide discriminatory input regarding the three proposed alternatives.

Representative CTEs were identified for the three alternatives, and subject matter experts (SMEs) were assigned to prepare TRL evaluations of the critical technologies. The CTEs are described in further detail along with the TRL evaluations in Volume 2, Section 6. These evaluations were performed using the TRL questionnaires and TRL scale (see Figure 4-4) included in the DOE guidance document. These questionnaires include programmatic, technical, and manufacturing criteria. Some non-technical criteria were not considered applicable at this pre-conceptual stage.

Operability and Maintainability including ALARA: Operations and maintenance of equipment within the K West Basin is performed remotely due to the high radiation dose rate from materials stored within the basin. Personnel are required to wear protective equipment such as a breathing respirator, anti-contamination and water barrier clothing, and safety harnesses to avoid falls. Personnel use long-reach tools and hoists to access equipment within the basin. There is limited access through grating to objects within the basin. The approximately 17-foot water depth in the basin provides shielding to reduce the radiation exposure to personnel. The visibility within the basin water can be quickly obscured when performing operating and maintenance activities that disturb materials contained within the basin.

ALARA radiation dose estimates were prepared by K Basin operations personnel for each of the conceptual alternatives, as provided in Volume 2, Section 8.8. The estimated total radiation dose for operations and maintenance activities at the K West Basin was approximately the same for all three alternatives, within the accuracy of the ALARA estimate. The estimated total radiation dose for operations and maintenance activities conducted on the 200 Area Central Plateau were the same for all alternatives.

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[25] Defense Nuclear Facility Safety Board Recommendations can be found at the following website http://www.dnfsb.gov/pub_docs/dnfsb/rec_2007.html

[26] Technology Readiness Assessment (TRA)/ Technology Maturation Plan (TMP) Process Guide (March 2008), U. S. Department of Energy Office of Environmental Management

ALARA, operability, and maintainability considerations for the three alternatives favor minimizing the placement of new equipment and minimizing sludge slurry movement activities within the K West Basin. Alternatives 6T/6N and 7T/7N install less equipment and perform fewer sludge movement activities within the K West Basin than alternatives 1T/1N, since sludge oxidation (i.e., treatment) is performed in a new facility located on the 200 Area Central Plateau.

Programmatic Aspects: Analysis of the programmatic aspects indicate that alternatives 6T and 7T have the shortest duration for Phase 1, which is estimated to be approximately two to three years less than the other alternatives. There appears to be no discrimination between alternatives for life-cycle schedule except that alternatives 7T/7N are complete one year later due to the heated drum storage to oxidize uranium metal. The Phase I costs for alternatives 6T and 7T are less than the other alternatives because less work is performed at the K West Basin and the costs to prepare T Plant are less than a new interim storage facility. The alternatives have similar total life-cycle costs. No differentiation can be made between the alternatives when considering impacts to WIPP or other programs. Integration with other K West Basin activities and T Plant can be managed for all alternatives.

The DSB rating and ranking of the three alternatives and the "T" and "N" sub-alternatives using these five criteria is summarized in Table 4 and is discussed in the following sections. The information presented by the STP subject matter experts to the DSB and used by the DSB to rate and rank these alternatives is discussed in further detail in Volume 2, Sections 7 through 9.

Table 4. Summary of DSB Rating and Ranking of Alternatives

Criteria	Weighting Factor	Weighted Score -- 1-T	Weighted Score -- 1-N	Weighted Score -- 6-T	Weighted Score -- 6-N	Weighted Score -- 7-T	Weighted Score -- 7-N
1. Safety	Go/ No Go	Go	Go	Go	Go	Go	Go
2. Regulatory/ Stakeholder Acceptance	25	75	75	100	50	75	25
3. Technical Maturity	20	60	60	60	60	20	20
4. Operability and Maintainability	25	50	50	75	75	75	75
5. Programmatic Aspects	30	90	60	120	60	120	60
Total Score		275	245	355	245	290	180

In addition to and consistent with the numerical rating for alternative 6T, it has the following advantages:

- Expeditiously reduces the nuclear safety risk to the public.
- Expeditiously reduces environmental risks by moving sludge safely away from the river, thereby allowing earlier remediation of the contaminant plume beneath the basin.
- Earliest possible closure of 100-K operable units as required by environmental and regulatory agreements.
- Does not preclude decision on ultimate disposition of the waste and preserves the option to combine treatment with other required facilities at Hanford.

- Avoids installation and operation of sludge treatment and packaging systems within the difficult operating environment of K West Basin.
- Lowest near-term cost while not resulting in any increase in long-term life-cycle cost.
- At least five to nine years quicker for removal of sludge from the Columbia River corridor than any alternative that immobilizes the waste at or near the basin.

<u>Other Background Material</u>

Hose-in-Hose

A central task in the Sludge Treatment Project is to retrieve the sludge from the K Basin and move it to whatever the subsequent processing might be. Earlier work requiring similar sludge retrieval employed a technology called "hose-in-hose." The results of using this approach were less than desired primarily due to a lack of understanding of the nature and character of the sludge[27]. Consequently, the hose-in-hose approach is not planned for this project.

Two-Phase Approach

The reason for separating this project into two phases is the key DOE objective of removing the sludge from the K-West Basin and River Corridor as soon as possible. Early removal reduces risks to the environment, allows for remediation of contaminated areas under the basins, and supports early closure of the 100-KR-4 operable unit.

Funding Levels

EM HQ guidance requires STP to stay within existing funding levels and have a high degree of certainty of success (greater than 80%). The current STP five-year (and 10-Year) funding profile cannot support design, construction, and operation of an in-basin treatment and packaging system due to: other higher site priorities; and, continued sludge retrieval and mobilization technical challenges thereby limiting its ability to achieve an 80% confidence level of success.

Regulatory Agreements

The U.S. Environmental Protection Agency and Washington Department of Ecology recently agreed to establish new 100 K Area milestones based mainly on the RL two phase approach to treat and package the K Basin sludge.

<u>Scope of Review</u>

The review focuses on several major areas: project management, technical risks, regulatory risks, system risks, safety risks, and risks associated with expert elicitation.

- Project management risks focus on cost, schedule, and baseline.

- Technical risks include what are the uncertainties? What are the critical technologies? What is the maturation state of these critical technologies? Can a suitable surrogate of the sludge be developed and retrieved?

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[27] Hose-in-Hose Sludge Transfer System, Technical Assessment of Fluor Hanford Inc.KE/KW Basins, January 2O-March 14,2005, Assessment Number: A-05-SED-SNF-011.

- Regulatory risks involve the effect of at-basin processing versus the two phase approach on nuclear safety. Also, do state or federal regulators favor one approach over another?

- There are risks associated with the system, itself. What is its operability? How easily can it be maintained? Which approach is easier to implement?

- Safety risks include those that go along with working with radioactive materials. What are they? What is their impact on the plan?

- The use of expert elicitation raises several questions. Are the conclusions reached valid and the methods used correct for the intended analysis? Does the available information support the conclusions?

Team Membership

The team members, 5 or more, will be independent experts whose credentials and experience align with the specific lines of inquiry (LOI) listed below and who collectively provide the team sufficient-broad capability and flexibility to address the full range of issues that may emerge in this review. Technical expertise includes, but is not limited to, design, engineering, process engineering-operability and maintainability of systems, project budgeting and schedule estimating, rheology, management of chemical processing and radioactive waste management systems. Individual expertise and field experience will be commensurate with the LOI. The experts must be free of any conflicts of interest with CHPRC and Waste Isolation Pilot Plant.

ETR members will not promote any technology, position taken by, or sludge disposition path they, their organizations, or their company may be associated with, or, developing to handle RH-TRU radioactive wastes. Also, ETR members shall not use information learned, from their review of the STP, as a vehicle to solicit future STP work from DOE-EM-HQ or RL.

Please refer to Attachment (1) for team member roster.

Period of Performance

The starting date of the External Technical Review has not been established. Due to schedule demands of individual team members, some portions of the Review may be performed to a slightly different time table.

Activity		Date
EM-211 ETR planning visit to Hanford		January 28, 2009
ETR on-site visit to Hanford • RL/STP presentation to ETR • Testing facility (MASF) walk-down • K West Basin walk-down		March 16 – 18, 2009

Activity		Date
Team Meeting-Draft Report		March 19 – 20, 2009
Final Report approved by Team Members		April 24, 2009
Briefing to EM Senior Management		April 30, 2009

Lines of Inquiry

The following Lines of Inquiry will be addressed by this External Technical Review:

Are project cost estimates performed with acceptable methodologies and accuracy for a project at the CD-0/CD-1 stage?

Are project schedule estimates performed with acceptable methodologies and accuracy for a project at the CD-0/CD-1 stage?

Are the technical approaches logical and developed at a reasonable level of detail for a project at the CD-0/CD-1 stage?

Are risks resulting from technology development, regulatory & legal obligations, system operability, and system maintainability adequately considered for a project at the CD-0/CD-1 stage?

Are the lessons learned from past sludge treatment and handling efforts being incorporated by the project?

Are the key project decisions supported by appropriate cost, schedule, and risk drivers?

Is there an adequate all encompassing strategy being developed to integrate all aspects of designing, constructing, operating, and decommissioning a sludge treatment system for processing 100 K West Basin sludge at Hanford?

> "Adequate" considers ability to reach technical maturity of each sludge treatment alternative, stay within the EM five year budget profile, have a high probability of success, meet regulatory commitments, meet WIPP and Yucca Mtn. WACs, and, promote the RL 2015 Vision.

Are the ROM estimated schedules and budgets of the seven STP alternatives logical and reasonable? Are they sufficient to permit the down selection?

Is there a need to build a new facility for Phase 1interim sludge storage? Phase 2 sludge treatment and packaging?

Are the benefits associated with early removal of the sludge from 100 K West Basin to the Central Plateau, prior to treatment and immobilization, attainable and reasonable for consideration?

Are the STP risks captured by the project reasonable and is there a plan to address them at actionable levels?

Is the project appropriately assigning resources (schedule, funds, and technical staff) to develop the needed first-of-a-kind technology from concept to field application?

APPROVALS

We, the undersigned, have read and approve this charter:

Mark A. Gilbertson
Deputy Assistant Secretary for
Engineering and Technology

3/13/09
Date

David A. Brockman
Manager, Richland Operations Office

3/12/09
Date

Attachment 1: Sludge Treatment Project External Technical Review Team Membership

Steven L. Krahn, DPA	DOE Office of Waste Processing (EM-21), *lead*
David Kosson, PhD	Department of Civilian Engineering, Vanderbilt University
David Gallay , DSc	Logistics Management Institute (LMI)
Jim Davis	DOE Office of Safety Management/Operations (EM-60)
David French	Waste Isolation Pilot Plant
Art Etchells, III	Consultant
G. Smith, PhD	DOE Office of Waste Processing (EM-21)

Attachment 2: ACRONYMS

CHPRC	CH2MHILL Plateau Remediation Company
CTE	Critical Technology Element
DOE	Department of Energy
DSB	Decision Support Board
EC	Engineered Container
EM	Office of Environmental Management
EPA	Environmental Protection Agency
ETR	External Technical Review
IWTS	Integrated Water Treatment System
KOP	Knockout Pot
LOI	Lines of Inquiry
MCO	Multi-Canister Overpacks
NLOP	North Loadout Pit
RH-TRU	Remote-Handled TRU Waste
RL	Richland Operations Office
ROD	Record of Decision
ROM	Rough Order of Magnitude
ST	Settler Tube
STP	Sludge Treatment Project
WAC	Waste Acceptance Criteria
WIPP	Waste Isolation Pilot Plant

Ross, Steven

From: Krahn, Steve
Sent: Thursday, March 26, 2009 2:05 PM
To: Gerdes, Kurt; 'Kosson, David S'; Ross, Steven
Subject: FW: T Plant vs. New Facility Study

David: revised approach approved.
Kurt/Steven: we should append this to the charter.

Steve
Steve Krahn
Phone: 202-586-2281
e-mail: steve.krahn@em.doe.gov

-----Original Message-----
From: Brockman, David A [mailto:David_A_Brockman@RL.gov]
Sent: Thursday, March 26, 2009 12:57 PM
To: Bryson, Dana C
Cc: Teynor, Thomas K; Krahn, Steve
Subject: FW: T Plant vs. New Facility Study

-----Original Message-----
From: Gilbertson, Mark [mailto:mark.gilbertson@em.doe.gov]
Sent: Thursday, March 26, 2009 9:51 AM
To: Brockman, David A
Subject: RE: T Plant vs. New Facility Study

Ok with me too.

-----Original Message-----
From: Brockman, David A [mailto:David_A_Brockman@RL.gov]
Sent: Thursday, March 26, 2009 10:19 AM
To: Krahn, Steve; Gilbertson, Mark
Cc: Teynor, Thomas K; Kosson, David S; Ross, Steven; Franco, Joe
Subject: RE: T Plant vs. New Facility Study

Ok with me

-----Original Message-----
From: Krahn, Steve [mailto:Steve.Krahn@em.doe.gov]
Sent: Thursday, March 26, 2009 4:52 AM
To: Gilbertson, Mark; Brockman, David A
Cc: Teynor, Thomas K; Kosson, David S; Ross, Steven; Franco, Jose R (Joe)
Subject: FW: T Plant vs. New Facility Study
Importance: High

Dave & Mark:

The FPD has requested, below, that the ETR Team incorporate some developing information into its review. As one phase of the review was to review the option of using T-Plant for interim-term storage or a 'new facility', if the concept for the 'new facility' is substantially evolving, I think that it would be of benefit to include this information in the review. The Team will continue to review the information associated with other options and the Technology Maturation approach in parallel.

I would envision us being able to provide a preliminary brief, with the caveat that we are awaiting this final information, to senior management if the two of you believe that it would provide value added. David Kosson & I will have to huddle, but I would imagine that this change would have us providing a final report closer to the end of May, vice the end of April.

I think that the additional insight would be worth the effort.

As the senior managers who approved the charter, I would appreciate your thoughts.

Steve
Steve Krahn
Phone: 202-586-2281
e-mail: steve.krahn@em.doe.gov

-----Original Message-----
From: Teynor, Thomas K [mailto:Thomas_K_Teynor@RL.gov]
Sent: Monday, March 23, 2009 7:38 PM
To: Krahn, Steve
Cc: Franco, Joe; Bryson, Dana C; Quintero, Roger A; Hill, Burton E (Burt); Gerdes,
Ross, Steven
Subject: T Plant vs. New Facility Study

Steve,

Thank you again for your frank, fair, and in depth review of our sludge treatment
One additional item I request the External Technical Review (ETR) team review and
comment on is the forthcoming contractor study comparing T Plant vs. a new
facility/storage pad. The contractor will have their final report to RL by 4-30-20

Please advise if this is agreeable. I do think the report may have a large impact
assessment of our project.

V/R Tom